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In August 1959, the President directed the Secretary of Health, Education, and Welfare, to intensify Departmental activities in the field of radiological health. The Department was assigned responsibility within the Executive Branch for the collation, analysis, and interpretation of data on environmental radiation levels such as natural background, radiography, medical and industrial uses of isotopes and X rays, and fallout. The Department delegated this responsibility to the Division of Radiological Health, Public Health Service.

Radiological Health Data and Reports, a monthly publication of the Public Health Service, includes data and reports provided to the Division of Radiological Health by Federal agencies, State health departments, and foreign governmental agencies. Pertinent original data and interpretive manuscripts are invited from investigators. These are subject to review by a Board of Editorial Advisors with representatives from the following Federal agencies:

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U.S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE
Public Health Service • Division of Radiological Health

STRONTIUM-90 CONCENTRATIONS OBSERVED IN U.S. PASTEURIZED MILK COMPARED WITH STRONTIUM-90 LEVELS IN PRECIPITATION, IN TOTAL DEPOSITION, AND IN SOIL, 1960-1963

Henry L. Fisher, James R. Coleman, and *Richard D. Grundy*[1]

SYNOPSIS: Annual averages of strontium-90 concentrations in milk were compared with precipitation, strontium-90 deposition, and strontium-90 in soil for the years 1960-1963 on the basis of linear relationship. This relationship may be useful for limited predictions of future strontium-90 concentrations in milk. As expected, higher concentrations of strontium-90 were found in milk from areas of higher concentrations of strontium-90 in soil, and higher milk concentrations seemed to be associated with increased rainfall. Although it was clear that increased deposition of strontium-90 was related to its concentration in milk, variations in the relationship remain to be studied on the basis of the specific transport mechanisms involved.

The Public Health Service's Pasteurized Milk Sampling Network (PMN) has been in operation since 1960. The data obtained from this network are routinely published in *Radiological Health Data and Reports* and have been recently summarized (*1*, *2*). The purpose of this review is to relate the strontium-90 concentrations observed in milk with such parameters as precipitation, strontium-90 deposition, and strontium-90 concentration in soils. Although these parameters have served in the development of rather detailed prediction models (*3*, *4*), only general comparisons will be made here, and comparisons for periods of time of less than one year will not be attempted. More detailed investigations relating to these parameters are currently in progress.

Annual precipitation

The average concentration of strontium-90 in milk and the total annual precipitation for each of the years 1960-1963 (*5*), are shown in figures 1 and 2, respectively. Using these data, the PMN stations were separated into three groups. Group One stations were located in an area where annual precipitation ranges from 0 to 16 inches, Group Two stations were located in areas where precipitation ranges from 16 to 32 inches, and Group Three stations were located in areas where precipitation ranges from 32 to 64 inches. For each of these groups, distributions of stations versus annual average strontium-90 concentration in milk were constructed and are shown in table 1.

Studies have shown that strontium-90 deposition is correlated with precipitation (*6-8*). The concept of "wet" areas (areas of greatest annual precipitation) and "dry" areas has been used with success to relate the strontium-90 content of milk and the total diet to the amount of annual precipitation (*9-10*). Comparison of average strontium-90 concentrations in milk to annual precipitation (table 1) for 1960-1963 indicates that the higher annual average strontium-90 content of milk is associated with greater annual precipitation or at least is associated with areas which have the higher annual precipitation.

[1] At the time of the preparation of this paper, Mr. Coleman was chief, Data Collation and Analysis Section, Radiation Surveillance Center, DRH, PHS, Washington, D.C., and Mr. Grundy and Mr. Fisher were staff members.

Table 1 also shows that not every station in a high precipitation area will have a high annual strontium-90 average. Likewise, every station in a low precipitation area will not necessarily have low annual average strontium-90 concentrations in milk. This point calls attention to the fact that there are other operative factors than the total amount of precipitation which influence strontium-90 concentrations in milk. Such factors include the height of the precipitation cloud, the precipitation generation and growth mechanism in the

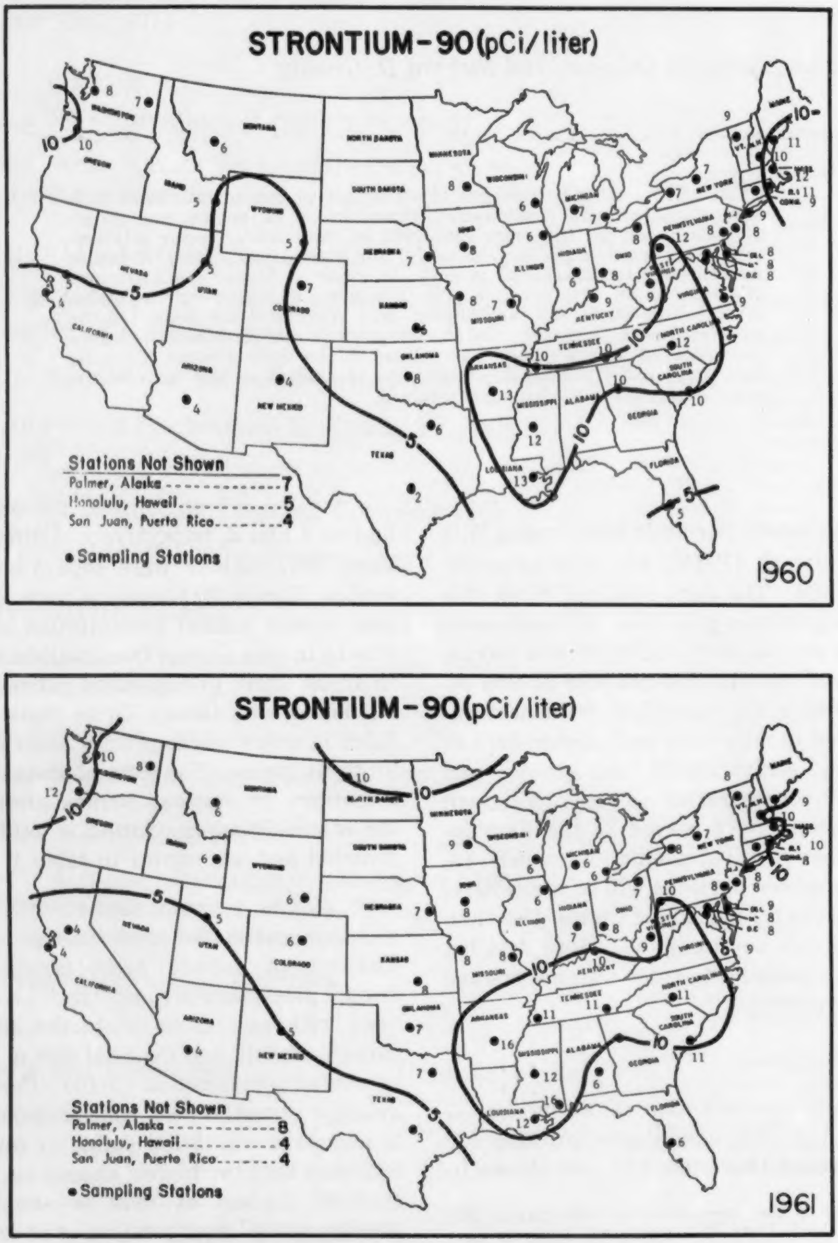
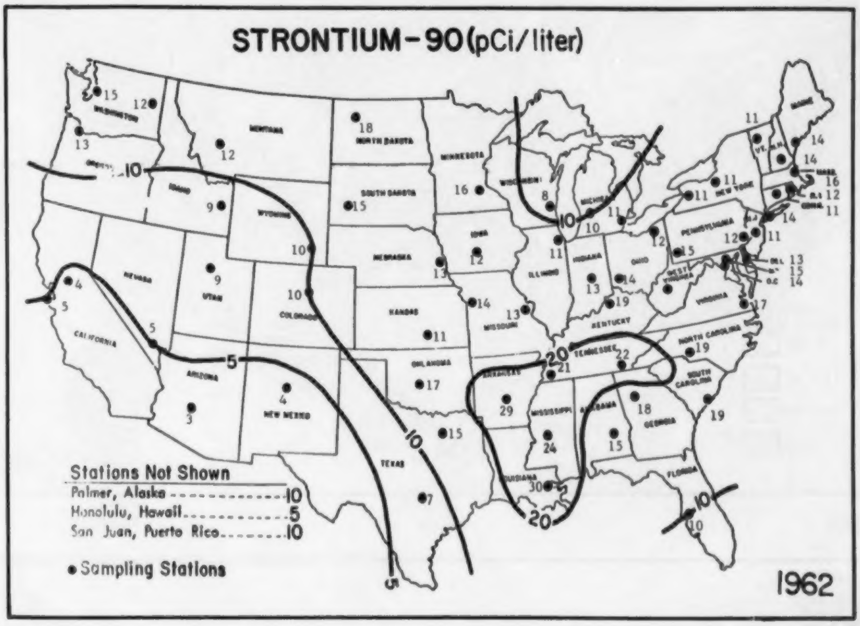


Figure 1. Annual average strontium-90 concentrations in milk, 1960-1963

clouds, and the amount and characteristics of the radioactive aerosols initially in the air versus participating in the precipitation process (*11*). It is reasonable to assume that variation in the growth of forage as a result of the amount of precipitation and relative soil richness is a contributing factor.



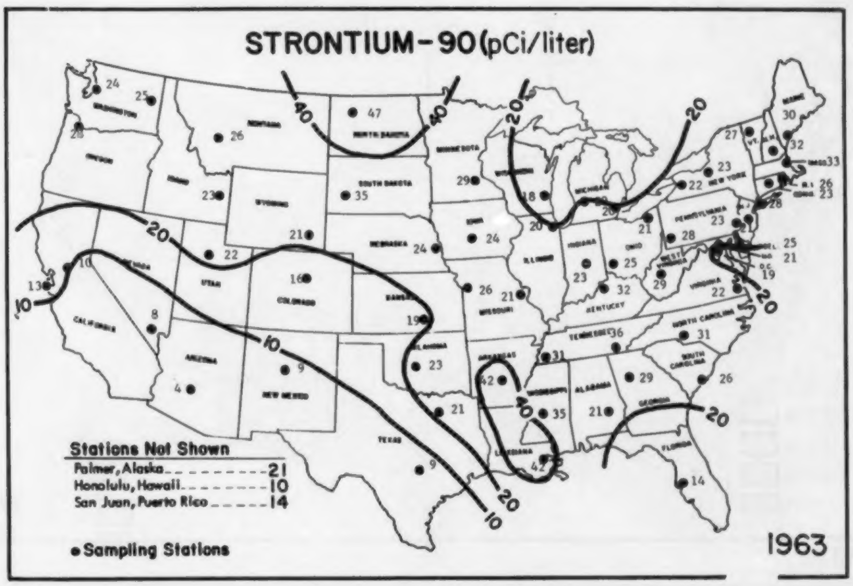
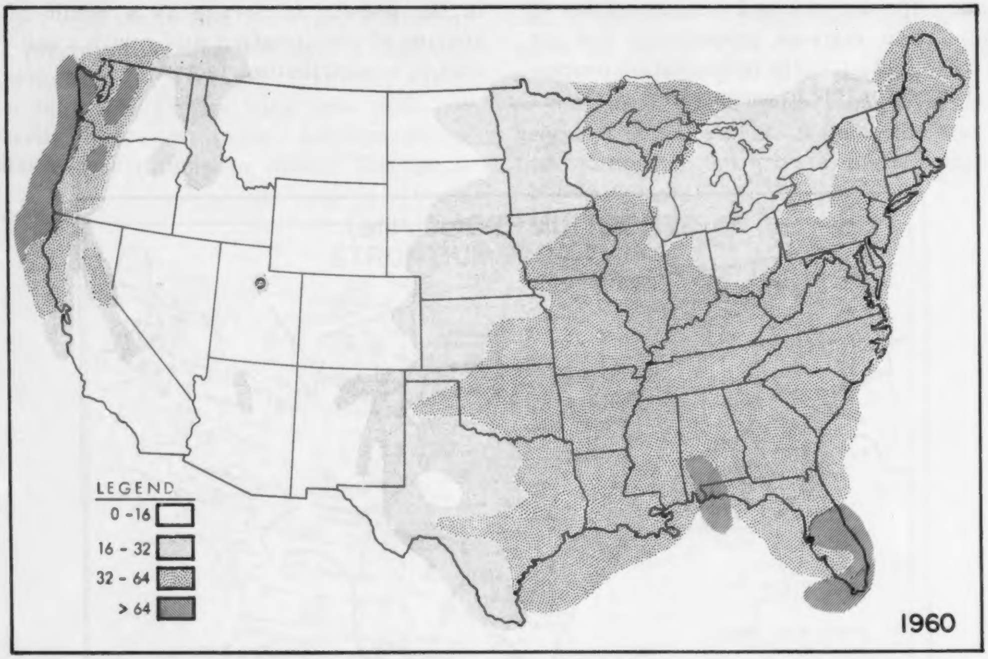


Figure 1. Annual average strontium-90 concentrations in milk 1960–1963—continued



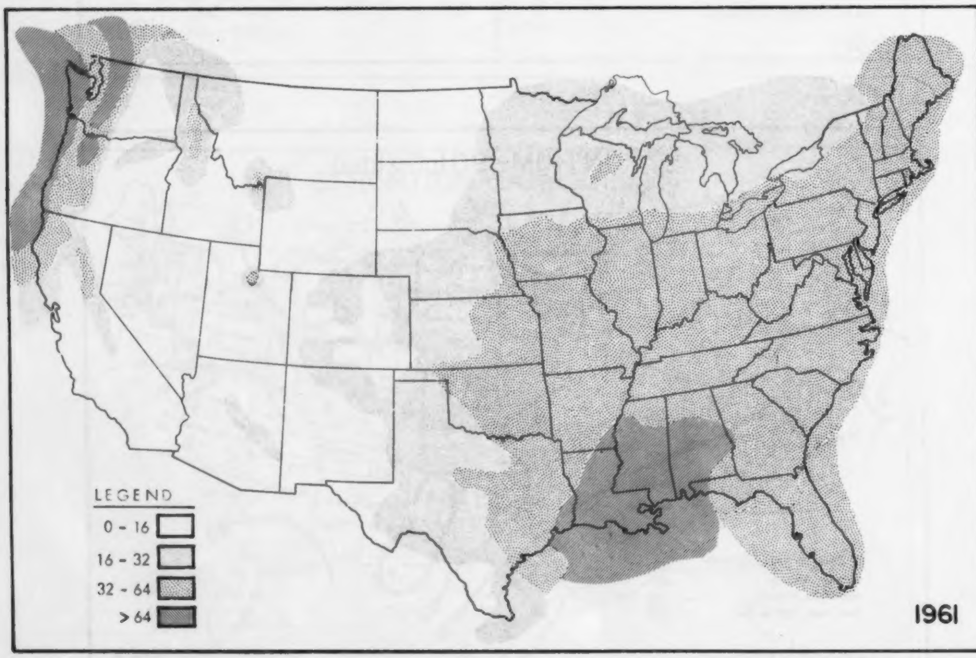


Figure 2. Total annual precipitation (inches), 1960–1963

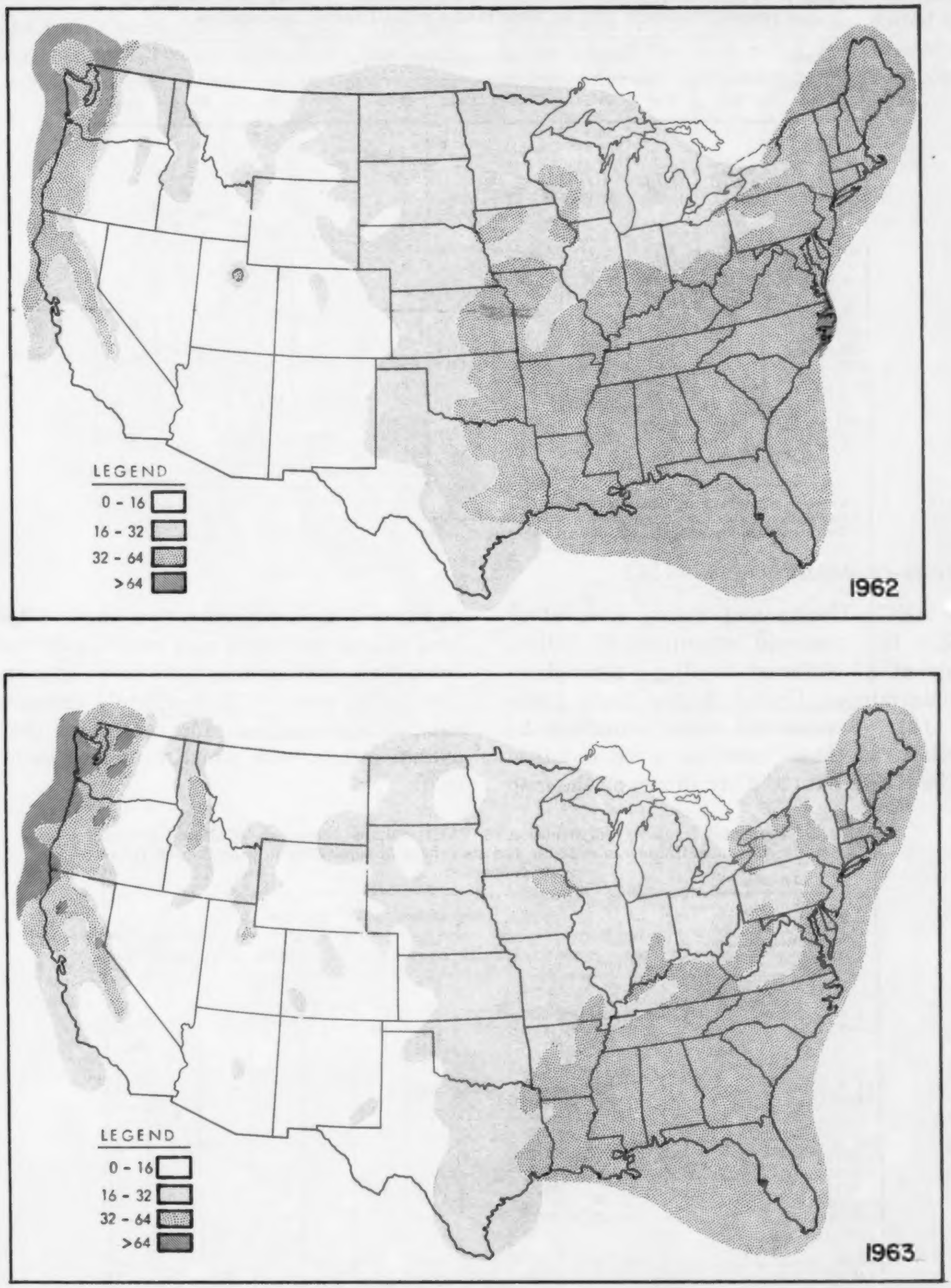


Figure 2. Total annual precipitation (inches), 1960-1963—Continued

ts

Table 1. Percental frequency distribution of PMN stations according to strontium-90 concentrations in milk for three ranges of total annual precipitation

Year and range of precipitation (inches)	Strontium-90, pCi/liter									
	0–4	5–9	10–14	15–19	20–24	25–29	30–34	35–39	40–44	45–49
1960										
0–16	[a] 4(2)	9(5)								
>16–32	2(1)	18(10)	2(1)							
>32–64	2(1)	40(22)	24(13)							
1961										
0–16	5(3)	7(4)	2(1)							
>16–32		11(6)								
>32–64	2(1)	[b] 49(28)	[c] 23(13)	2(1)						
1962										
0–16	3(2)	3(2)	3(2)							
>16–32	2(1)	3(2)	16(9)	7(4)						
>32–64		2(1)	31(18)	21(12)	5(3)	2(1)	2(1)			
1963										
0–16	2(1)	3(2)		2(1)		2(1)				
>16–32		2(1)	3(2)	3(2)	20(12)	10(6)	2(1)	2(1)		2(1)
>32–64			2(1)	2(1)	17(10)	12(7)	8(5)	3(2)	3(2)	

[a] Values in parenthesis are number of stations.
[b] One station in this group had rainfall greater than 64 inches.
[c] Two stations in this group had rainfall greater than 64 inches.

Strontium–90 deposition, 1960-1963

The AEC's Health and Safety Laboratory (HASL) has analyzed strontium–90 fallout monthly at 27 different locations throughout the conterminous United States from 1960–1963 (*12*). The annual total strontium–90 depositions at these locations were obtained from the HASL data and are shown on the map in figure 3 as isoconcentration lines. Although local fallout variations may result in differences from these contour maps, the value at each station is the sum of 12 completely independent samples and analyses and represents the best available data with which to derive such contours.

Table 2. Percental frequency distribution of PMN stations according to annual average strontium-90 concentrations in milk for various ranges of total annual strontium-90 fallout deposition

Year and range of ^{90}Sr deposition, mCi/mi^2	Strontium-90 in milk, pCi/liter										
	0–4	5–9	10–14	15–19	20–24	25–29	30–34	35–39	40–44	45–49	Avg.
1960											
0–4	[a] 7(4)	35(19)	9(5)								6.9
>4–8		33(18)	16(9)								9.0
1961											
0–4	7(4)	12(7)	2(1)								5.6
>4–8		54(31)	21(12)	2(1)							8.7
>8–12			2(1)								10.0
1962											
>8–12	3(2)		2(1)								5.7
>12–16	2(1)	3(2)	3(2)								11.0
>16–20		3(2)	12(7)	12(7)							13.7
>20–24			28(16)	7(4)	5(3)	2(1)					15.1
>24–28			2(1)	9(5)							15.8
>28–36		2(1)	3(2)								10.7
1963											
>8–16	2(1)	5(3)			2(1)						10.2
>16–24			3(2)	2(1)	2(1)				2(1)		20.8
>24–32				2(1)	7(4)	7(4)	2(1)	3(2)	2(1)	2(1)	28.8
>32–40				2(1)	5(3)	7(4)	3(2)	2(1)			26.6
>40–48			2(1)		8(5)	3(2)					22.1
>48–56				2(1)	7(4)	2(1)					21.8
>56–64					7(4)	5(3)	5(3)				26.6

[a] Values in parenthesis are number of stations.

To develop a distribution of strontium-90 deposition versus annual average strontium-90 concentrations in milk, the following procedure was employed: the strontium-90 deposition was divided into a number of ranges, and the PMN stations which were situated in each range according to figure 3, were tabulated. For each of these sets, a distribution of stations versus annual average strontium-90 in milk concentrations was developed. The resulting compound station distributions may be seen in table 2.

These distributions are shown graphically in figure 4. Each vertical bar is plotted at the midpoints of the milk concentration and deposition intervals. A smoothed curve connects

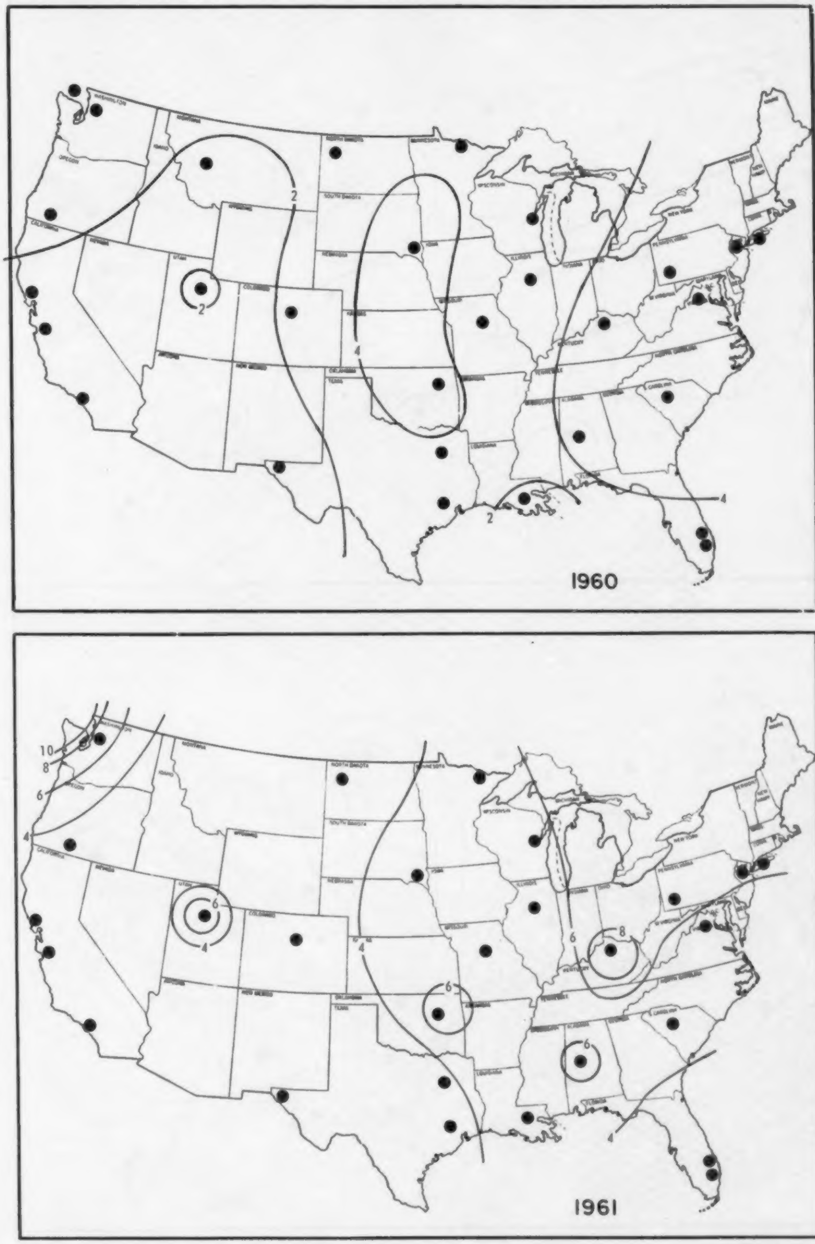


Figure 3. Total annual strontium-90 fallout deposition (mCi/mi^2) 1960–1963

the tops of the bars to provide an indication of the continuous distribution in the plane of fixed deposition. The compound distribution would be a smoothed surface passing through the curves shown.

Figure 4 indicates that the dispersion of strontium-90 levels in milk was small in 1960 and 1961. Strontium-90 deposition in 1962 and 1963 was much greater than in 1960 and 1961 (see figure 3). Increased annual average strontium-90 concentration in milk is associated with increased total average strontium-90 deposition, but much more variability in milk levels is seen at these greater deposition levels (*13*).

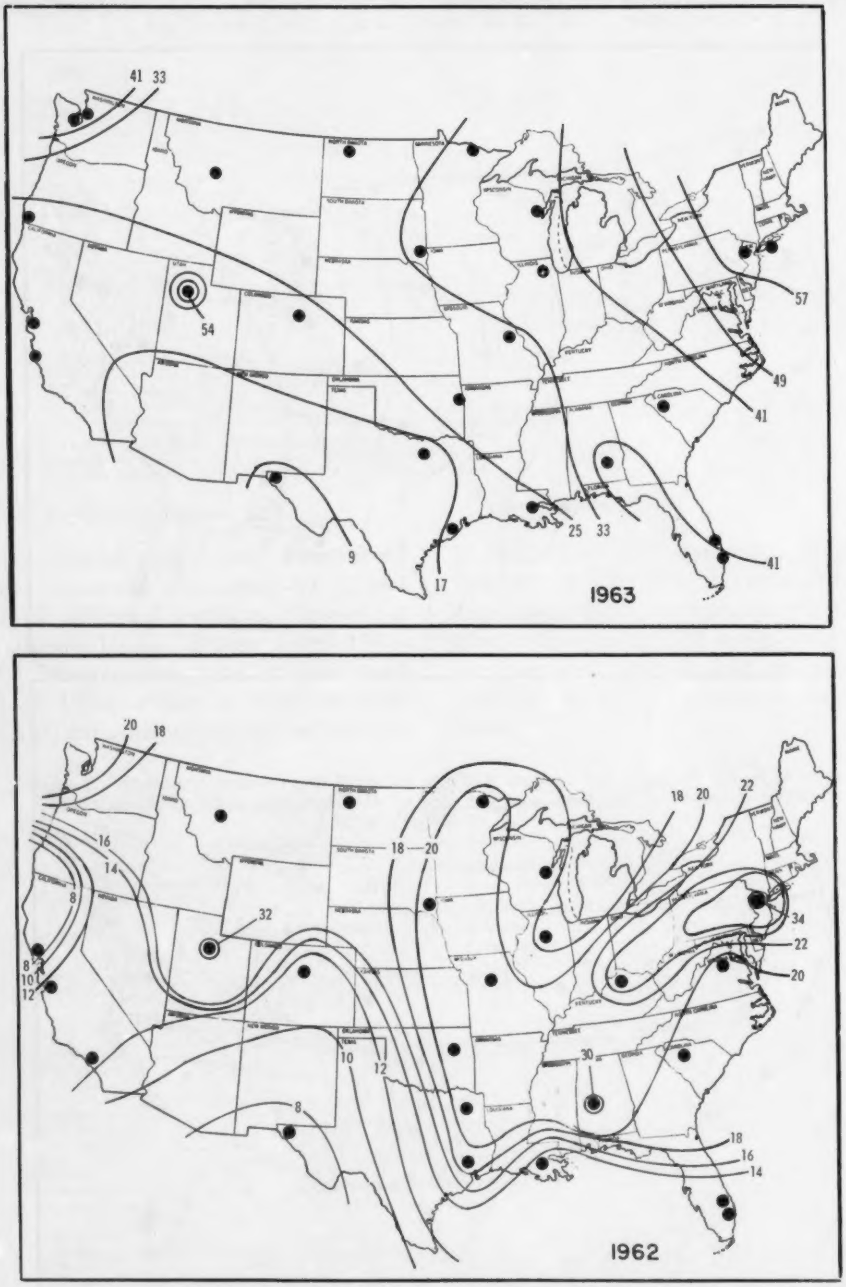


Figure 3. Total annual strontium-90 fallout deposition (mCi/mi²) 1960-1963—continued

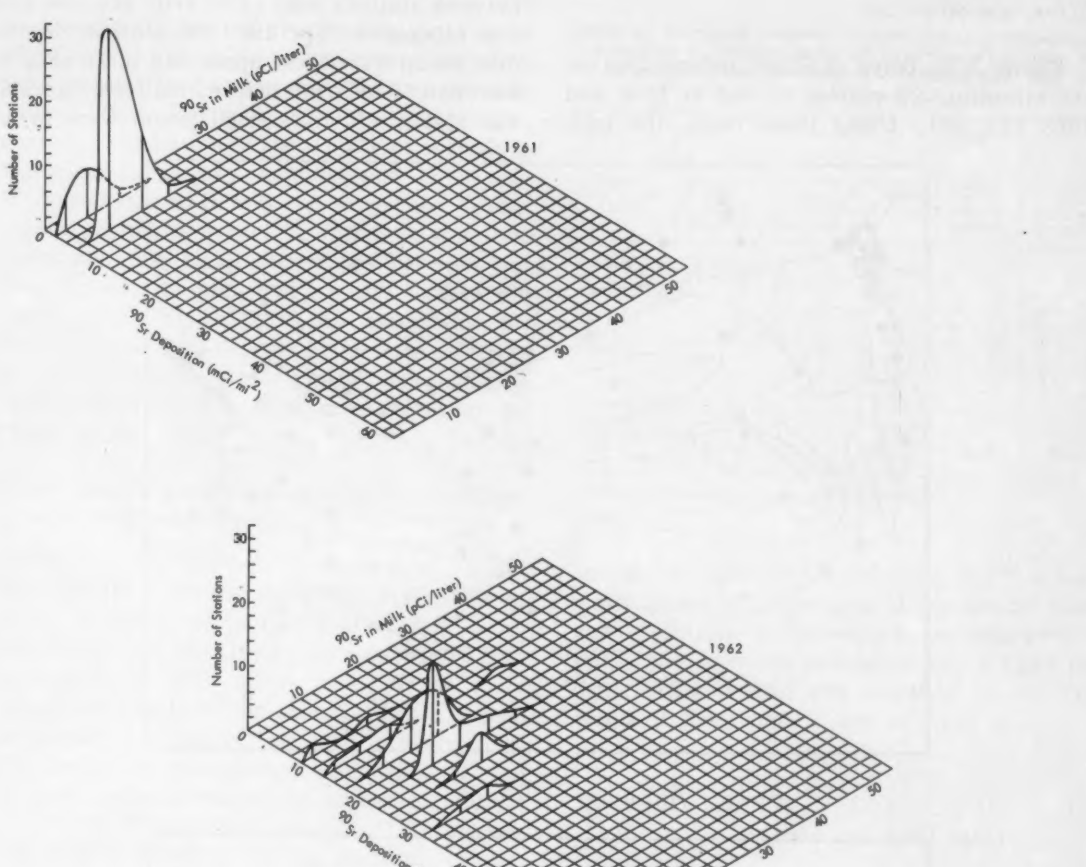


Figure 4. Compound distributions for strontium-90 in deposition versus strontium-90 in milk, 1961–1963

Strontium-90 in soil

Figure 5 portrays available information on the strontium-90 content of soil in 1960 and 1963 (*14, 15*). Using these maps, the milk network stations were arbitrarily grouped into two categories. For 1960 the stations in the first group were those appearing in an area of less than 60 mCi/mi² determined from figure 5. The stations in the second group were in an

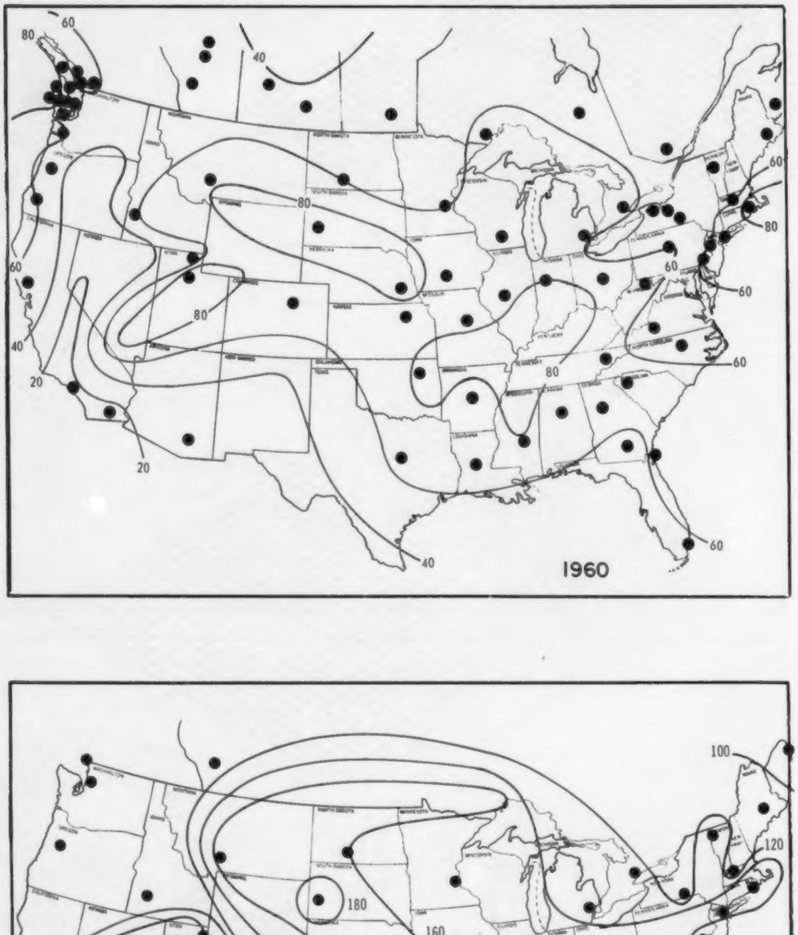


Figure 5. Strontium-90 in soil (mCi/mi²) in conterminous United States and southern Canada in 1960 and 1963

area with a soil level of greater than or equal to 60 mCi/mi². For 1963, the two groups were less than 140 mCi/mi² and greater than or equal to 140 mCi/mi². For each set of stations, a percentage distribution of these stations according to various ranges of annual average strontium–90 concentrations in milk was developed. These results are shown in table 3. It may be seen that there are only small differences between the distributions for high and low soil content for either year. This supports the concept that recent strontium–90 deposition is more effective in influencing the strontium–90 concentration in milk than the translocation of strontium–90 from the soil (*16*).

Table 3. Percental frequency distribution of PMN stations according to concentrations of strontium-90 in milk for two groups of the strontium-90 content of soil, 1960 and 1963

1960			1963		
Range of ^{90}Sr in milk (pCi/liter)	^{90}Sr in soil <60 mCi/mi² (percent)	^{90}Sr in soil ≥ 60 mCi/mi² (percent)	Range of ^{90}Sr in milk (pCi/liter)	^{90}Sr in soil <140 mCi/mi² (percent)	^{90}Sr in soil ≥ 140 mCi/mi² (percent)
0–2	5 [a] (1)	3 (1)	0–4	4 (1)	
>2–4	17 (3)	11 (–)	5–9	11 (3)	
>4–6	11 (2)	21 (8)	10–14	11 (3)	
>6–8	39 (7)	34 (13)	15–19	4 (1)	10 (3)
>8–10	22 (4)	24 (9)	20–24	40 (11)	34 (11)
>10–12	6 (1)	13 (5)	25–29	15 (4)	31 (10)
>12–14		5 (6)	30–34	7 (2)	13 (4)
			35–39	4 (1)	6 (2)
			40–44	4 (1)	3 (1)
			45–49		3 (1)
Average (pCi/liter)	7.0	8.3	Average (pCi/liter)	21.0	26.8

[a] Numbers in parentheses are number of stations.

Least squares analysis of strontium–90 content of milk, soil, and deposition

There are a number of factors which apparently influence the strontium–90 content of milk. However, as indicated previously, a relationship may exist between strontium–90 concentration in milk and several of the more prominent factors mentioned. It has been previously suggested that for a given area the strontium–90 content of milk can be related linearly to the strontium–90 deposition and the strontium–90 content of soil (*3, 17*). Using this concept, an equation may be written:

$$M_i = aD_i + bS_i \tag{1}$$

where

M_i = strontium–90 concentration in milk (pCi/liter),
D_i = annual strontium–90 fallout deposition (mCi/mi²),
S_i = strontium–90 content of soil (mCi/mi²), and "a" and "b" are constants.

Using the data on the strontium–90 content of soil for 1960 and 1963 in figure 5 and the strontium–90 deposition for 1960 and 1963 in figure 3, each PMN station was assigned a strontium–90 soil level and an annual strontium–90 deposition for the years 1960 and 1963. These data, along with the annual average strontium–90 concentration in milk at each PMN station for 1960 and 1963, were used to determine, by least squares analysis, the constants "a" and "b" in equation 1. The root mean square ($\sigma_{\hat{x}}$) deviation of the annual average strontium–90 concentration observed in milk (M_i) from the calculated values ($\mathcal{M}_i$) for both 1960 and 1963 was also determined. The result of these calculations is given by:

$$\mathcal{M}_i = 0.16D_i + 0.13\ S_i \qquad i = 1, \ldots, 114 \tag{2}$$
$$\text{(1960 and 1963 data)}$$

and yield $\sigma_{\hat{x}}$ (1960) and $\sigma_{\hat{x}}$ (1963) of 3 and 6 pCi liter, respectively.

These results may be compared with the values reported by the U.N. Scientific Committee (*16*) after conversion of units. Given in terms of mCi/km² and pCi/g Ca, the values of "a" and "b" calculated above are 0.35 and 0.29, respectively (assuming a milk calcium concentration of 1.18 g/liter). The worldwide range of values of "a" reported in the above reference (on the basis of 1960 data) is from 0.3 to 1.5, with an average of 0.78. The U.S. value was 0.7. Similarly, values of "b" range from 0.21 to 0.80, with an average of 0.37. The U.S. value was 0.27.

It is interesting to identify the stations in which the calculated milk result was different

from the observed annual average by $2\sigma_z$ or more. In 1960, the $2\sigma_z$ value was 6 pCi/liter, and these stations and their associated M_i-M_i are as follows:

Station	M_i-M_i
Indianapolis, Indiana	–6
Omaha, Nebraska	–6
Salt Lake City, Utah	–7

In 1963, the 2σ value was 14 pCi/liter and these stations and their associated M_i-M_i are as follows:

Station	M_i-M_i
Little Rock, Arkansas	18
New Orleans, Louisiana	25
Minot, North Dakota	21

Although the sign variation in M_i-M_i from 1960 to 1963 could be the result of chance, the change is significant and shows a tendency to overestimate 1960 values and underestimate 1963 values. This would seem to imply that the effect of deposition has been underestimated and the effect of soil levels overestimated. It is more likely that these stations could have very different "a" and "b" factors from the other stations, or that the method of determining strontium–90 fallout levels and soil levels at each milk sampling station based on contour map interpolation has introduced the variations. It is always possible that month-to-month variations in the strontium–90 deposition may introduce additional inaccuracy, since the analysis used in this paper is based on yearly time intervals. In spite of these difficulties, this approach is reasonable in terms of obtaining results within the limits of error stated.

The U.S. Weather Bureau predicted the annual strontium–90 fallout deposition for 1964 and 1965 (*8*). These values are 10 mCi/mi² (range 5 to 25) for 1964 and 5 mCi/mi² (range 3 to 15) for 1965, and an average soil level of 140 mCi/mi² (range 60 to 180) for 1963. The average strontium–90 concentration in milk in the United States from equation 2 in 1964 and again in 1965 would be approximately 20 pCi/liter in both 1964 and 1965. The observed range for 1964 was 4 to 54 pCi/liter with an average of 25 (*1*), while the observed range for 1965 was 5 to 42 pCi/liter, with an average of 17.5 pCi/liter. These values again point out the failure of the parameter to predict closely the range of observations but yielding a reasonable value for the average. Assuming negligible strontium–90 fallout after 1965, the average strontium–90 concentration in milk in 1966 would be 19 pCi/liter and thereafter would decrease at the same rate as the soil level. However, any strontium–90 deposition resulting from atmospheric testing since the limited test ban treaty would tend to raise this value.

Summary and discussion

This report has discussed the annual variation of strontium–90 in milk as related to precipitation and strontium–90 in deposition and in soil. For ease of analysis, each of these factors was first examined alone in relation to radionuclide levels in milk. However, it should be pointed out that milk sampled by the PMN is that distributed in an area. Therefore, milk shipped into an area from other locations would be expected to affect the correlation with fallout in the area sampled. Although such effects are assumed to be small, they are factors contributing to unexplained variability.

As expected, higher milk levels occurred generally in those areas where soil levels were greater, although this was not universally the case. Higher milk levels also seemed to be associated with increased precipitation.

Strontium–90 fallout deposition was compared with the annual average strontium–90 concentrations in milk. Although the expected effect that increased deposition relates to increased milk levels was apparent, there still were unexplained variations which suggest that other factors must be considered if an accurate description of strontium–90 concentrations in milk is to be found.

The strontium–90 concentrations in milk were assumed to be related to both the strontium–90 content of soil and strontium–90 deposition. Although only approximate, the results

based on this relationship could possibly be used for limited predictions of future strontium-90 concentrations in milk (provided strontium-90 soils levels and strontium-90 deposition can be predicted), as well as providing insight into the relative influence of deposition and soil levels on milk concentration.

It is emphasized that this review is of a general type, based on annual parameters for a large area (the United States), and is not intended to prove or disprove the validity of specific mechanisms of radionuclide behavior in the environment. Such parameters as fallout and weather over short periods of time, microgeographical variation in strontium-90 in soil, and farming practices would undoubtedly explain many of the apparent temporal and geographical anomalies of strontium-90 concentrations in milk when considered on a regional or national scale.

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RADON-222 IN NATURAL GAS

Louis A. Bunce and *Frank W. Sattler*[1]

SYNOPSIS—In the preoperational phase of a study to determine the effect of an underground nuclear detonation on radon levels in natural gas, baseline levels of radon–222 have been measured during 1965 in natural gas from 307 producing wells in the proposed test area. Average radon–222 levels in natural gas from formations sampled varied from 2.7 to 66.9 pCi/liter, with a maximum observed value of 158.8 pCi/liter. Assuming combustion in a room without discrete ventilation radon–222 buildup from an original fuel concentration of 50 pCi/liter could produce a room concentration of 1 pCi/liter in the New Mexico area where the gas would be used. This estimated concentration equals the maximum exposure level permitted by regulations of the State of New Mexico (based on NCRP limits) under conditions on continuous or general population exposure. Normal use of natural gas would not be expected to produce radon–222 concentrations in excess of these recommended limits.

Radon–222[2] has been measured in natural gas from wells in northwestern New Mexico and southwestern Colorado, jointly by personnel of the U.S. Public Health Service and the El Paso Natural Gas Company. The purpose of this study was to establish baseline levels of radon–222 in natural gas in this area prior to initiation of "Project Gasbuggy" (*1*), a proposed underground nuclear detonation planned by the Atomic Energy Commission and the El Paso Natural Gas Company aimed at increasing productivity of a low-flow gas reservoir.

In 1963, 10 pCi/liter of radon–222 was observed in the natural gas supply to the Public Health Service Laboratory at Farmington, New Mexico. Because the radon–222 is a naturally occurring radionuclide which contributes to background radiation, and its presence in natural gas represents a possible source of radiation exposure to humans as well as a source of interference in low-level radiometric analyses, the laboratory staff decided to obtain further information on the radon content of natural gas in the area. The El Paso Natural Gas Company was asked to collaborate on this project and agreed to do so.

When Project Gasbuggy was proposed, the authors, anticipating that the detonation might affect radon levels in natural gas in the area, enlarged the project to include measurement of radon–222 levels in gas both before and after Project Gasbuggy.

The joint venture began in 1965. This report contains results of the initial series of gas analyses. There is no definite date for Project Gasbuggy at present; however, subsequent to the test, the Public Health Service and the El Paso Natural Gas Company plan again to assay the natural gas in the area to determine the effects of the detonation on radon–222 levels.

Procedure

During 1965, gas samples were collected by the El Paso Natural Gas Company personnel from 307 producing wells, principally in the Mesaverde, Pictured Cliffs, and Dakota Formations of the San Juan Basin in northwestern New Mexico and southwestern Colorado. Samples were collected at the well heads in metal cylinders containing approximately 0.75 liter. The sample cylinders were tagged with the well number, location, sample time, and date.

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[1] Mr. Bunce is now with the Utah State Health Department, Salt Lake City, Utah. He was formerly with the Research Branch, Division of Radiological Health, Public Health Service, U.S. Department of Health, Education and Welfare, Farmington, New Mexico. Mr. Sattler is with the El Paso Natural Gas Company, Farmington, New Mexico.

[2] Radon–222 is a heavy gaseous radionuclide formed by the radioactive decay of radium–226. It has a half-life of 3.8 days and decays by emission of an alpha particle.

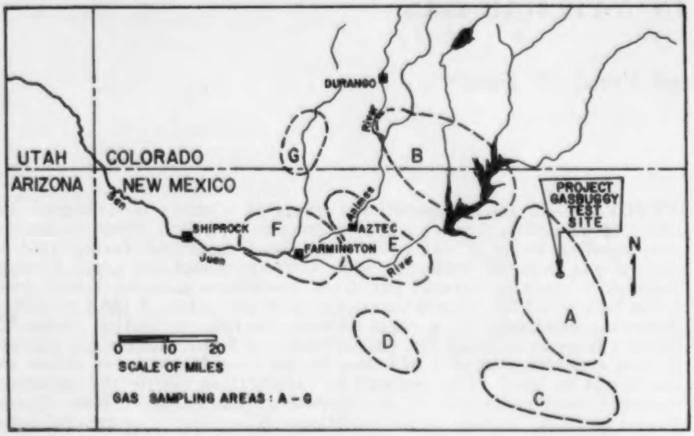

Figure 1. Natural gas sampling locations in the San Juan Basin

Samples were analyzed for radon–222 in the Public Health Service laboratory in Farmington, operated under contract with the New Mexico State Department of Health. Radon–222 was determined by alpha scintillation counting using a modification method described by Lucas (*2*). Gas samples were stripped of daughter products by bubbling through a weak acid solution, then were dried and transferred to the counting chamber. After aging for 4 hours, samples were counted and corrected for daughter ingrowth. Correction was also made for use of natural gas in lieu of nitrogen as the carrier gas.

Results

Table 1 presents the radon–222 levels found in natural gas samples collected from different geological formations in the areas shown in figure 1. All radon–222 values are corrected to the time of sample collection at the well head.

The radon–222 levels varied from a low of 0.2 pCi/liter of gas to a high of 158.8 pCi/liter. The radon–222 content in the Dakota formation showed very little variation from area to area. The mean radon–222 levels in this formation ranged from 9.1 pCi/liter in area A to 12.1 pCi/liter in area E. Only 8 of the 75 wells

Table 1. Radon-222 levels in natural gas, 1965

Area [a]	Formation	Number of wells sampled	Well depths, feet		Radon-222 level, pCi/liter		
			Mean	Range	Mean	Maximum	Minimum
A	Mesaverde	55	6,268	5,686–6,924	26.1	55.2	0.3
	Dakota	7	8,011	7,798–8,330	9.1	14.0	4.4
	Pictured Cliffs	26	4,241	3,860–4,572	14.5	26.9	0.2
B	Mesaverde	64	5,731	5,133–6,615	32.3	158.8	5.9
	Dakota	36	7,930	7,346–8,363	10.3	23.0	2.2
	Fruitland	11	2,655	2,293–3,054	2.7	12.9	0.5
C	Pictured Cliffs	16	3,137	2,062–3,850	66.9	158.8	12.8
D	Dakota	6	6,655	6,196–6,974	11.9	25.7	4.4
	Pictured Cliffs	6	2,216	1,721–4,021	56.2	115.6	6.4
	Gallup	5	6,057	5,503–6,289	22.4	33.9	12.1
E	Mesaverde	22	4,722	3,318–5,056	21.4	34.5	5.4
	Dakota	8	6,854	6,538–7,696	12.1	16.1	8.0
	Pictured Cliffs	9	2,496	2,180–3,310	38.6	65.1	11.5
F	Dakota	18	6,431	6,097–7,211	9.3	20.7	3.4
	Pictured Cliffs	5	2,178	960–3,478	41.5	73.8	21.9
	Fruitland	5	1,481	978–1,774	30.7	42.4	5.4
G	Paradox	8	9,138	8,680–9,552	21.0	62.1	5.4

[a] Lettered areas shown in figure 1.

sampled in this formation showed radon levels greater than 20 pCi/liter, with the highest being 25.7 pCi/liter. The Mesaverde Formations showed a similiar consistency in mean radon–222 levels (Areas A, B, and C), although a wider range of concentrations (0.3 to 158.8 pCi/liter) was observed.

On the other hand, in the Pictured Cliffs Formation, samples from wells in area A averaged 14.5 pCi/liter radon–222, while those from areas C and D averaged 66.9 and 56.2 pCi/liter, respectively. Samples from this formation in areas E and F averaged 38.6 and 41.5 pCi/liter radon–222.

Table 2 shows the radon–222 levels found in the gas supplied to the radiological laboratory at Farmington. The values are for grab samples collected at the laboratory gas outlet in July 1963 and on 6 days in October 1965. The radon–222 level was much higher in October 1965 than in the summer of 1963[3].

Eleven wells were sampled twice, with a 3-month interval between. Table 3 shows the variation in radon–222 levels observed in each well. In each case, concurrent gas samples were collected from these wells by El Paso Natural Gas Company and analyzed chemically. The carbon dioxide nitrogen, and hydrocarbon content in the gas of both samples from each well were essentially the same, but some variations in radon–222 concentrations were observed in different samples from a given well. It is likely that the gas flow from a well at the time of sampling has a significant effect on the radon–222 content. A radon–222 profile on a well, developed over the period of a year under different production conditions, should be quite useful in evaluating radon–222 variation and the effect of gas flow rate on radon–222 buildup.

[3] It appears likely that the difference observed might be explained by several variables, including changes in rate of gas usage and relative depletion of reservoirs. Obviously, different concentrations would result if different wells were used as sources of the gas, but this could not be verified for the periods studied. The El Paso Natural Gas Company normally commingles gas from the Pictured Cliffs, Dakota, and Mesaverde formations before the gas leaves the San Juan Basin. Another company operating in this general area—the Southern Union Gas Company—also commingles gas from various formations.

Table 2. Radon-222 in natural gas at Farmington laboratory

Date	Radon-222 (pCi/liter)
July 1963	10.0
October 1965	48.8
	53.0
	49.4
	50.6
	51.0
	52.6
Mean, six October grab samples	50.9

Table 3. Variation of radon-222 within gas wells

Formation	Well number	Sample taken (1965)	Radon-222 level (pCi/liter)
Mesaverde (Area A)	70-813	July	20.0
		October	11.4
	70-814	July	22.2
		October	0.8
	71-335	July	30.6
		October	15.7
	72-331	July	31.4
		October	79.1
Pictured Cliffs (Area A)	70-736	June	17.8
		September	14.8
	71-172	June	14.3
		September	11.9
	71-329	July	12.4
		October	8.9
	71-988	July	20.5
		October	25.5
	71-995	July	7.5
		October	9.1
Paradox (Area G)	75-036	May	51.2
		August	3.1
	76-170	May	13.1
		August	16.0

Evaluation of possible hazard to humans

Radon–222 levels in air as a result of burning natural gas can be compared to the maximum limits recommended by the International Commission on Radiological Protection (ICRP) and to the regulations of the State of New Mexico.

The maximum expected buildup of radon–222 would likely occur in a closed room containing unvented gas appliances (such as a large burner, a gas range with oven, or an unvented space heater). Since the natural gas produced in this area is predominantly methane, combus-

tion of 1 liter of the gas will produce approximately 1 liter of carbon dioxide. Therefore, the radon–222 buildup from burning gas in a closed area would be proportional to that of carbon dioxide.

Normal ventilation in an occupied room would probably be such that the carbon dioxide level in the room air would not rise above 2 percent.[4] Thus, the radon–222 level in the room would not be expected to rise above 2 percent of its original concentration in the unburned gas. This would be 1 pCi/liter, assuming an original radon–222 concentration of 50 pCi/liter, the level observed in the gas at the laboratory at Farmington, New Mexico.

The upper limit recommended by the ICRP for continuous radon–222 exposure in air for the general population is 0.33 pCi/liter (*3*). The State of New Mexico regulations (*4*) are based on the report of the National Committee on Radiation Protection (*5*), which recommends an upper limit of 1 pCi/liter radon-222 in air to which large populations are continuously exposed outside of controlled areas. Thus, even assuming the extremely unfavorable conditions stated, the radon–222 level would not exceed the State's limit.

Although the estimated radon–222 concentrations added to the air under these conditions would approximate the NCRP recommended limit for continuous exposure to the general population, this situation would be neither continuous nor general. It would likely occur only in limited populations since any appreciable transmission time from well to consumer would decrease the radon–222 content at a rate of 50 percent every 3.8 days. In addition, exposure would not be continuous, but would be limited to time spent indoors. Under normal conditions, where the gas flame itself is vented in accordance with State regulations, accumulation of radon–222 would be expected to be considerably smaller than the estimated levels.

[4] Assuming that the gas flame itself is properly vented as generally required by State regulations.

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Section I. Milk and Food

In the determination of the internal exposure to man from environmental radiation sources, primary interest centers on radionuclides in the diet. Efforts are being made by both Federal and State agencies to monitor the intake of various radionuclides in the total diet on a continuing basis. Although the total diet is the most direct measure of intake of radionuclides, indicator foods may be used to estimate dietary intake where specific dietary data are not available. As fresh milk is consumed by a large segment of the United States population and contains most of the biologically significant radionuclides from nuclear test debris which appear in the diet, it is the single food item most often used as an indicator of the population's intake of radionuclides. Moreover, it is the major source of dietary intake of short-lived radionuclides. In the absence of specific dietary information, it is possible to approximate the total daily dietary intake of selected radionuclides as being equivalent to the intake represented by the consumption of 1 liter of milk. More direct estimates of dietary intake of radionuclides than those furnished by indicator foods can be obtained by analyses of the total diet or representative principal food items or groups combined with appropriate consumption data.

The Federal Radiation Council has developed Radiation Protection Guides (RPG's) for controlling normal peacetime operations, assuming continuous exposure from intake by the population at large (*1-3*). The RPG's do not and cannot establish a line which is safe on one side and unsafe on the other; they do provide, however, an indication of when there is a need to initiate careful evaluation of exposure (*3*). Additional guidelines are provided by the FRC Protective Action Guides (*4*) and by the International Commission on Radiological Protection (*5, 6*).

Data from selected National, International, and State milk and food surveillance activities are presented herein. An effort has been made to present a cross-section of routine sampling programs which may be considered of a continuing nature. Routine milk sampling has been defined as one or more samples collected per month.

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NATIONAL AND INTERNATIONAL MILK SURVEILLANCE

As part of continuing efforts to assess man's exposure to radionuclides, various National and International organizations routinely monitor radionuclide levels in milk. In addition to those programs reported below, *Radiological Health Data and Reports* coverage includes:

Program	Period reported	Last presented
Radiostrontium in Milk, HASL	July–December 1965	June 1966
United Kingdom Milk	1962–1965	June 1966

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1. Pasteurized Milk Network April 1966

Division of Radiological Health and Division of Environmental Engineering and Food Protection, PHS

The Public Health Service's Pasteurized Milk Network (PMN) was designed to provide nationwide surveillance of radionuclide concentrations in milk through sampling from major milk production and consumption areas. The present network of 63 sampling stations (figure 1), provides data on milk in every State. In addition, milk is sampled in the Canal Zone and Puerto Rico. The most recent description of the sampling and analytical procedure employed by the PMN appeared in the December 1965 *Radiological Health Data* (*1*).

Figure 1. Pasteurized Milk Network sampling stations

Table 1. Average radionuclides concentration in pasteurized milk for the first quarter and April 1966 [a]

Sampling locations		Strontium-90 (pCi/liter)		Cesium-137 (pCi/liter)	
		First quarter 1966	April 1966	First quarter 1966	April 1966
Ala:	Montgomery	12	12	25	25
Alaska:	Palmer	14	14	40	35
Ariz:	Phoenix	4	3	15	15
Ark:	Little Rock	26	28	40	35
Calif:	Sacramento	6	12	15	20
	San Francisco	7	11	20	20
C.Z:	Cristobal	4	3	25	25
Colo:	Denver	11	12	25	25
Conn:	Hartford	11	12	40	40
Del:	Wilmington	13	17	40	40
D.C:	Washington	12	12	30	30
Fla:	Tampa	11	9	105	120
Ga:	Atlanta	19	19	40	35
Hawaii:	Honolulu	5	6	35	30
Idaho:	Idaho Falls	13	14	40	40
Ill:	Chicago	11	13	35	45
Ind:	Indianapolis	12	13	30	30
Iowa:	Des Moines	14	12	30	30
Kans:	Wichita	13	14	20	20
Ky:	Louisville	16	16	25	20
La:	New Orleans	29	30	40	45
Maine:	Portland	15	18	65	70
Md:	Baltimore	13	13	30	25
Mass:	Boston	14	15	60	60
Mich:	Detroit	11	12	35	40
	Grand Rapids	14	13	45	45
Minn:	Minneapolis	20	19	40	45
Miss:	Jackson	23	24	25	25
Mo:	Kansas City	15	13	20	30
	St. Louis	15	15	30	25
Mont:	Helena	15	15	60	65
Nebr:	Omaha	15	12	25	30
Nev:	Las Vegas	7	6	20	25
N.H:	Manchester	18	18	75	80
N.J:	Trenton	12	14	40	35
N. Mex:	Albuquerque	6	6	15	20
N.Y:	Buffalo	10	11	40	40
	New York	13	13	45	40
	Syracuse	10	13	40	40
N.C:	Charlotte	20	17	30	25
N. Dak:	Minot	31	32	45	45
Ohio:	Cincinnati	12	14	25	30
	Cleveland	13	13	35	40
Okla:	Oklahoma City	13	13	25	20
Ore:	Portland	12	14	35	40
Pa:	Philadelphia	12	14	35	35
	Pittsburgh	17	17	45	50
P.R:	San Juan	8	7	25	20
R.I:	Providence	12	14	45	45
S.C:	Charleston	23	19	45	40
S.Dak:	Rapid City	19	19	45	40
Tenn:	Chattanooga	21	20	25	35
	Memphis	17	17	15	15
Tex:	Austin	6	5	15	10
	Dallas	14	16	20	20
Utah:	Salt Lake City	13	12	40	40
Vt:	Burlington	14	15	55	55
Va:	Norfolk	16	14	25	30
Wash:	Seattle	15	15	40	50
	Spokane	15	15	40	45
W. Va:	Charleston	14	15	25	25
Wis:	Milwaukee	11	10	40	45
Wyo:	Laramie	14	10	30	25
Network average		13.8	14.2	35	36

[a] Calcium analyses were discontinued as of March 31, 1966; strontium-89 analyses were discontinued except for a minimum of 10 percent of selected samples: all analyses were <5 pCi/liter with the exception of a composite sample collected April 15 and April 22 at Omaha, Nebraska, which had a value of 15 pCi/liter. All iodine-131 and barium-140 values were below detectable levels.

The averages for April and the first quarter of 1966 are presented in table 1. The average monthly radionuclide concentrations are based on results obtained from samples collected weekly. If radionuclide values are below minimum detectable concentrations (*1*), averages are calculated using one-half the minimum detectable value.

For comparative purposes, distributions of strontium–90 and cesium–137 are presented in tables 2 and 3 for April 1965, and November 1965 through April 1966. The average strontium–90 concentrations in pasteurized milk from selected cities are presented in figure 2. During April 1966, the monthly average iodine–131 and barium–140 concentrations in milk were less than 10 pCi/liter.

Table 2. Frequency distribution, strontium-90 concentration in milk at PMN stations for April and November–December 1965 and January–April 1966

Strontium-90 (pCi/liter)	Number of stations						
	1965			1966			
	Apr	Nov	Dec	Jan	Feb	Mar	Apr
Under 10	5	9	9	10	9	9	8
10–19	23	43	43	46	46	44	50
20–29	27	9	11	6	7	7	3
30–39	5	2	0	1	1	3	2
40–49	2	0	0	0	0	0	0
50–59	0	0	0	0	0	0	0
60–69	1	0	0	0	0	0	0

Table 3. Frequency distribution, cesium-137 concentrations in milk at PMN stations for April and November–December 1965 and January–April 1966

Cesium-137 (pCi/liter)	Number of stations						
	1965			1966			
	Apr	Nov	Dec	Jan	Feb	Mar	Apr
Under 50	7	57	51	57	56	56	55
50–99	35	5	11	5	6	6	7
100–149	18	1	1	1	1	1	1
150–199	3	0	0	0	0	0	0

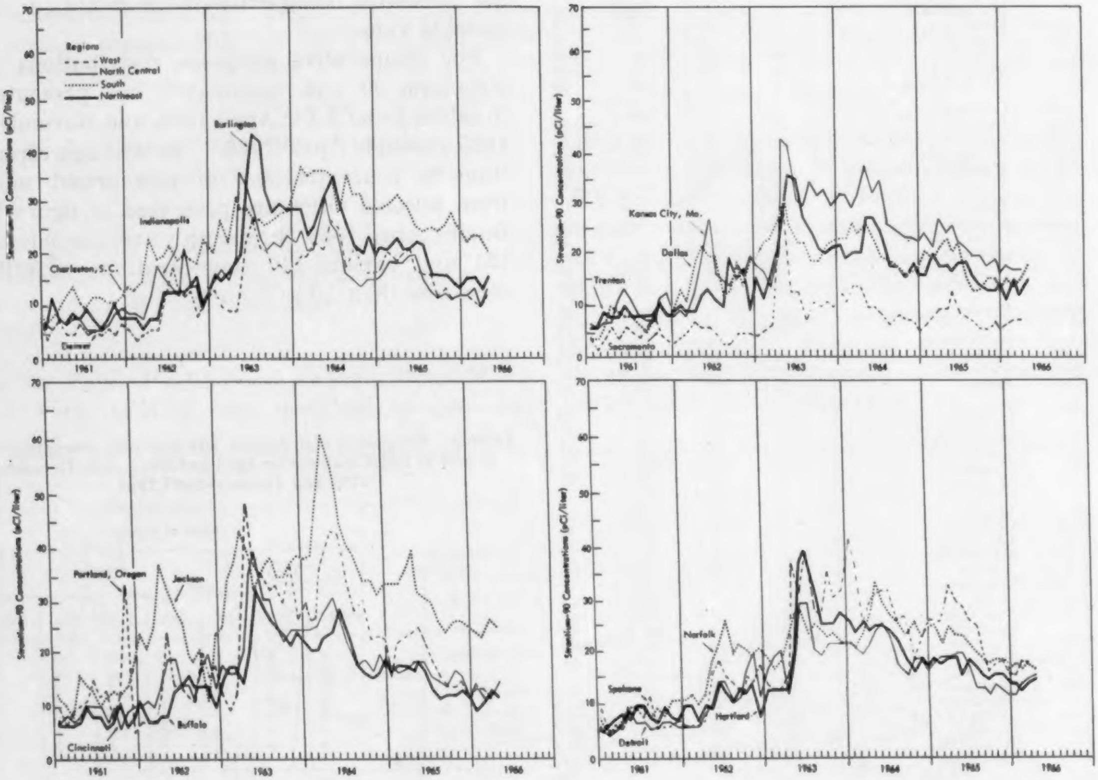

Figure 2. Strontium-90 concentrations in pasteurized milk, 1961-April 1966

2. Canadian Milk Network April 1966[1]

Radiation Protection Division
Department of National Health and Welfare
Ottawa, Canada

Since November 1955, the Radiation Protection Division of the Canadian Department of National Health and Welfare has been monitoring milk for radionuclide concentrations. Powdered milk was originally sampled, but liquid whole milk has been sampled since January 1963. At present, 16 milk sampling stations (figure 3) are in operation. Their locations coincide with air and precipitation sampling stations.

Milk samples are collected three times a week from selected dairies and are combined into weekly composites. The contribution of each dairy to the composite sample is directly proportional to the liquid volume of sales. Weekly spot check analyses are made for iodine–131, and monthly composites are analyzed for strontium–90, cesium–137, and stable calcium and potassium. The analytical procedures were outlined in the December 1965 issue of *Radiological Health Data* (2).

The April 1966 monthly average strontium–90, cesium–137, and stable calcium and potassium concentrations in Canadian whole milk are presented in table 4.

[1] Prepared from May 1966 monthly report, "Data from Radiation Protection Programs," Canadian Department of National Health and Welfare, Ottawa, Canada.

Table 4. Stable elements and radionuclides in Canadian whole milk, April 1966

Station	Calcium (g/liter)	Potassium (g/liter)	Strontium-90 (pCi/liter)	Cesium-137 (pCi/liter)
Calgary	1.13	1.4	19.2	73
Edmonton	1.11	1.5	16.9	61
Ft. William	1.04	1.5	24.6	48
Fredericton	1.13	1.5	28.0	79
Halifax	1.13	1.5	21.5	71
Montreal	1.10	1.6	15.5	50
Ottawa	1.15	1.6	12.0	43
Quebec	1.08	1.6	29.0	90
Regina	1.09	1.5	17.0	37
St. John's, Nfld.	1.10	1.6	24.8	67
Saskatoon	1.14	1.5	17.9	41
Sault Ste. Marie	1.04	1.6	22.1	75
Toronto	1.13	1.6	8.5	33
Vancouver	1.06	1.6	23.3	100
Windsor	1.12	1.5	6.7	37
Winnipeg	1.06	1.6	17.2	69
Average	1.10	1.5	19.0	61

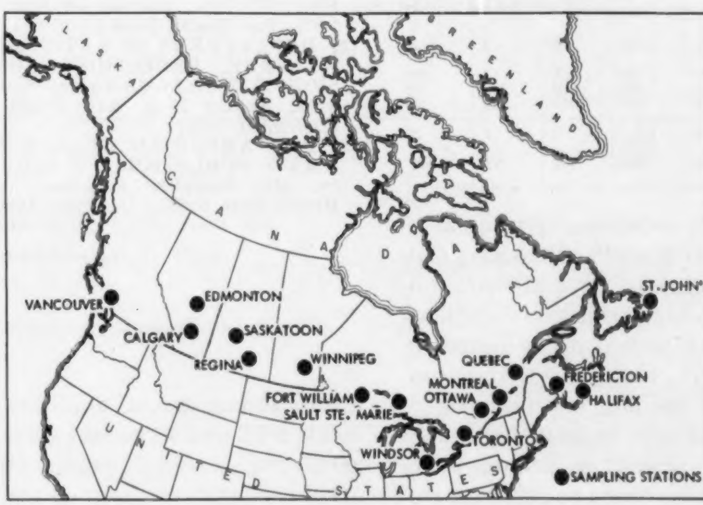

Figure 3. Canadian milk sampling stations

3. Pan American Milk Sampling Program April 1966

Pan American Health Organization and U.S. Public Health Service

The Pan American Health Organization (PAHO), in collaboration with the U.S. Public Health Service (PHS), furnishes assistance to health agencies in the American Republics in developing national radiological health programs.

Under a joint agreement between both agencies, air and milk sampling activities are conducted by a number of PAHO member countries (figure 4). Results of the milk sampling program are presented below. Further information on the sampling and analytical procedures employed was presented in the December 1965 issue of *Radiological Health Data* (*3*).

Table 5 presents stable calcium and potassium, strontium–90, strontium–89, and cesium–137 monthly average concentrations.

Table 5. PAHO stable element and radionuclide concentrations in milk, April 1966

Sampling station	Calcium (g/liter)	Potassium (g/liter)	Strontium-89 (pCi/liter)	Strontium-90 (pCi/liter)	Cesium-137 (pCi/liter)
Canal Zone:					
Cristobal	NS	1.38	0	3	25
Jamaica:					
Kingston	1.20	1.39	<5	13	205
Mandeville	NS	NS	NS	NS	NS
Montego Bay	NS	NS	NS	NS	NS
Puerto Rico:					
San Juan	NS	1.5	0	7	20
Venezuela:					
Caracas	NS	NS	NS	NS	NS

NS, no sample collected.

Figure 4. Pan American Milk Network sampling locations

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STATE MILK SURVEILLANCE ACTIVITIES

Considerable progress has been made by the State health departments in initiating or expanding environmental surveillance activities in radiological health. Many of the States now have comprehensive environmental surveillance programs supported by functional radiological health laboratories.

The continuing efforts of State health departments in the analysis and monitoring of radionuclides in milk complement Federal milk surveillance activities. State milk surveillance activities are continually undergoing developmental changes at this time. The results presented herein are representative of current surveillance activities directed toward the use of milk as an indication of dietary intake radioactivity.

In addition to the State milk networks presented herein, programs previously covered in *Radiological Health Data and Reports* include:

Milk network	Period reported	Last presented
California	October–December 1965	June 1966
Colorado	October–December 1964	April 1965
Florida	January–March 1966	July 1966
New York	July–December 1965	May 1966
Oklahoma	January–March 1966	July 1966
Oregon	October–December 1965	June 1966
Texas	January–March 1966	July 1966
Washington	October–December 1965	June 1966

1. Connecticut Milk Network January-March 1966

Connecticut State Department of Health

The Connecticut State Department of Health has been monitoring pasteurized milk for strontium–89 and strontium–90 since April 1960. In May 1962, the program was expanded to include the determination of gamma-emitting radionuclides in milk.

The sampling program is flexible in nature, providing for sampling in five areas of the State (figure 1). At the present time, a monthly sample representative of milk sold in the central area of the State is collected and analyzed for strontium–89, strontium–90, and gamma emitters. Concentrations of iodine–131 are determined as an indication of the presence of radioactivity of recent origin.

Strontium–89 and strontium–90 are determined by chemical separation. Iodine–131 and other gamma emitters are determined by gamma-scintillation spectroscopy.

The monthly average concentrations of strontium–89, strontium–90, iodine–131, and cesium–137 in Connecticut pasteurized milk are presented in table 1. These results are presented graphically in figure 2.

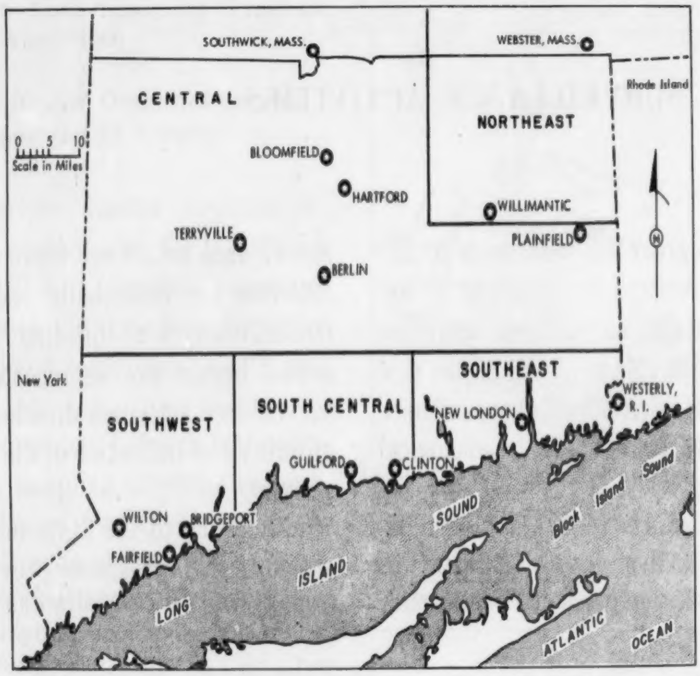

Figure 1. Connecticut pasteurized milk sampling areas

Table 1. Radionuclide concentrations in central Connecticut milk, January–March 1966

Month	Concentration, pCi/liter			
	Strontium-89	Strontium-90	Iodine-131	Cesium-137
January	<1	12	<10	40
February	<1	12	<10	30
March	<1	12	<10	40

Recent coverage in *Radiological Health Data and Reports:*

Period	Issue
April 1960–December 1962	May 1963
Annual summary 1963	September 1964
Annual summary 1964	May 1965
Annual summary 1965	May 1966

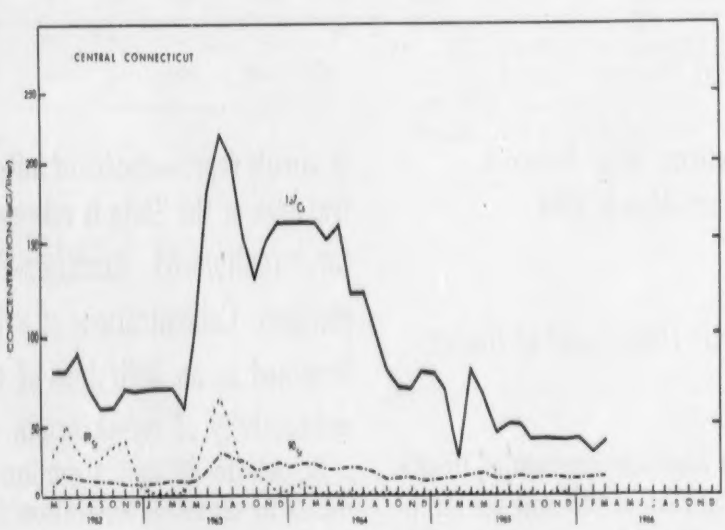

Figure 2. Radionuclide concentrations in Connecticut pasteurized milk

2. Indiana Milk Network January-March 1966

Bureau of Environmental Sanitation
Indiana State Board of Health

The Indiana State Board of Health began sampling pasteurized milk for radionuclide analysis in September 1961. The State was geographically divided into five major milksheds: northeast, northwest, central, southeast, and southwest (figure 3). One large dairy within each milkshed was assumed to be representative for sampling purposes.

Monthly analyses are performed for strontium-89, strontium-90, cesium-137, iodine-131, and barium-140, and for calcium and potassium-40. When iodine-131 concentrations exceed 100 pCi/liter, the sampling frequency is increased. Since August 1963, because of the continued low concentrations of short-lived radionuclides, the sampling frequency has been once a month for the northeast, southeast, and southwest milksheds.

Strontium-89 and strontium-90 concentrations in milk samples are determined by ion exchange separation (*1,2*), while cesium-137, iodine-131, and barium-140 are determined by gamma-scintillation spectrometry (*3*).

The monthly radionuclide concentrations in Indiana pasteurized milk are presented by station in table 2 for January through March 1966. During this period the monthly concentrations of strontium-89, iodine-131, and barium-140 remained below limits of detectability (*3*).

The monthly network average concentrations of strontium-89, strontium-90, and cesium-137 are presented graphically in figure 4.

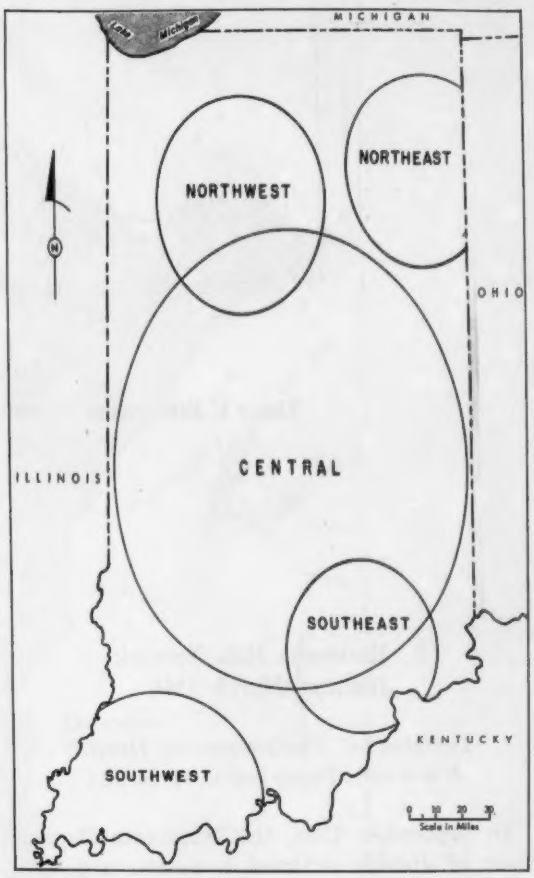

Figure 3. Indiana pasteurized milk sampling areas

Recent coverage in *Radiological Health Data and Reports:*

Period	Issue
Summary 1961-1964	May 1965
Annual summary 1965	May 1966

Table 2. Radionuclides in Indiana milk, January-March 1966

Sampling locations	Calcium, g/liter			Potassium-40, pCi/liter			Strontium-90, pCi/liter			Cesium-137, pCi/liter		
	Jan	Feb	Mar	Jan	Feb	Mar	Jan	Feb	Mar	Jan	Feb	Mar
Northeast	1.17	1.17	1.15	1,400	1,360	1,400	10	9	10	30	25	25
Southeast	1.17	1.17	1.21	1,340	1,590	1,460	15	14	15	25	40	30
Central	1.17	1.15	1.15	1,360	1,370	1,320	14	10	10	30	25	25
Southwest	1.15	1.19	1.15	1,360	1,390	1,350	12	11	13	25	25	20
Northwest	1.17	1.15	1.15	1,400	1,420	1,370	13	10	13	30	30	30
Average	1.17	1.17	1.16	1,370	1,430	1,380	13	11	12	30	30	25

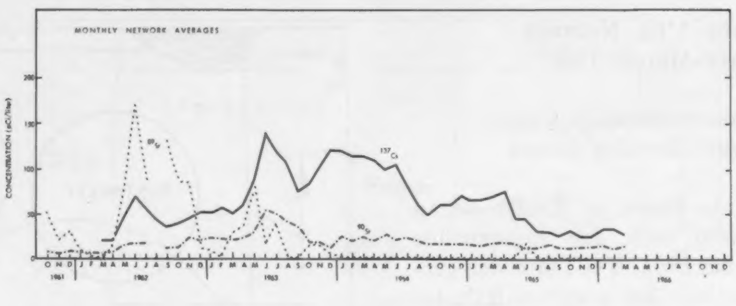

Figure 4. Radionuclide concentrations in Indiana pasteurized milk

3. Minnesota Milk Network January–March 1966

Division of Environmental Health
Minnesota Department of Health

In September 1958, the Minnesota Department of Health initiated a pasteurized milk network to monitor strontium–90 concentrations. Presently, monthly samples are collected from eight sampling locations in milksheds geographically the same as the Minnesota health districts (figure 5) and analyzed for strontium–90, iodine–131, and cesium–137. One-liter samples of processed Grade-A fluid milk are collected at bottling machines in pasteurization plants. The samples are customarily collected in the cities where the Minnesota Health District offices are located. However, it is sometimes convenient to collect at other locations. Such samples are considered representative of the district concerned.

Strontium–90 concentrations are determined radiochemically, while iodine–131 and cesium–137 concentrations are determined by gamma-scintillation spectrometry. The analytical procedures are presented in the semiannual report of the Minnesota Department of Health and Rural Cooperative Power Association (4).

Strontium–90 (table 3), iodine–131 (table 4), and cesium–137 (table 3), concentrations in milk are given for January through March 1966. The strontium–90, cesium–137, and iodine–131 concentrations in Minnesota pasteurized milk are presented graphically by milkshed in figure 6 for the period 1962–March 1966.

Table 3. Radionuclide concentrations in Minnesota milk January–March 1966

Sampling location	Month	Strontium-90 (pCi/liter)	Cesium-137 (pCi/liter)
Bemidji	January	29	80
	February	31	81
	March	25	80
Mankato	January	12	32
	February	11	57
	March	11	52
Rochester	January	14	33
	February	14	48
	March	13	36
Duluth	January	26	58
	February	24	62
	March	37	143
Worthington	January	14	32
	February	14	41
	March	7	40
Minneapolis	January	24	64
	February	15	21
	March	17	60
Fergus Falls	January	17	50
	February	16	55
	March	15	52
Little Falls	January	20	53
	February	18	62
	March	19	59
Average	January	19	50
	February	18	53
	March	18	65

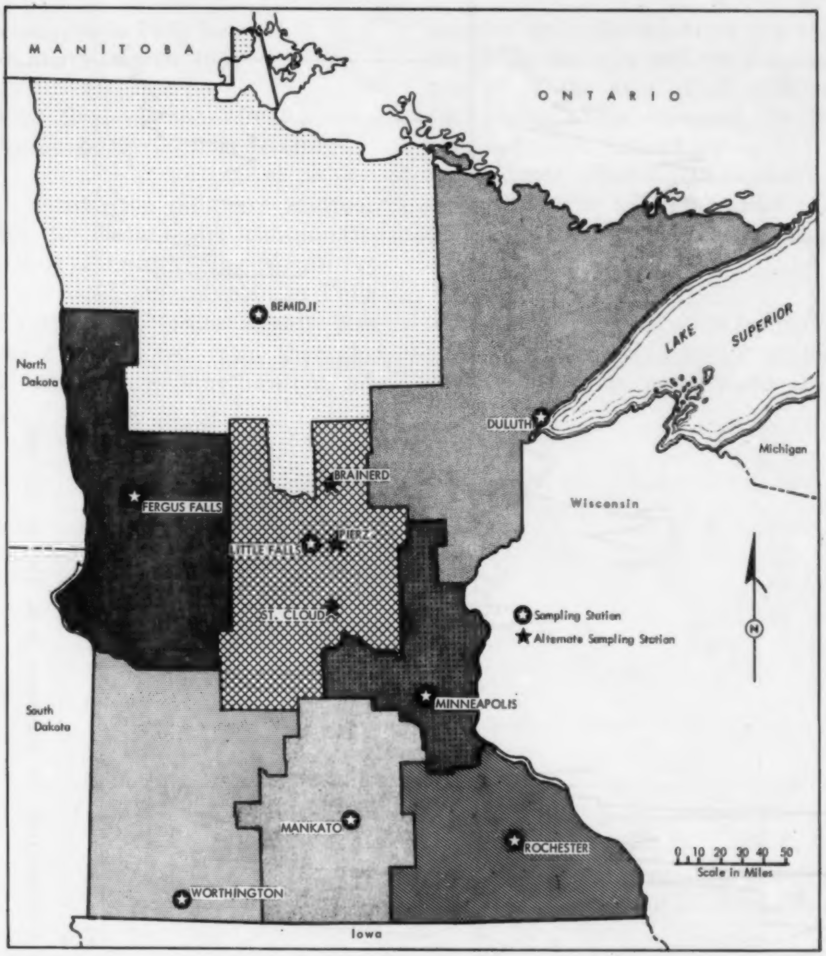

Figure 5. Minnesota milk sampling locations

Table 4. Iodine-131 concentrations in Minnesota milk January–March 1966

Collection point	Collection date 1966	Iodine-131 (pCi/liter)
Bemidji	February 8	11
	March 7	10
Little Falls	March 7	12
Worthington	March 7	16

Note: The results given are single values. The remaining 20 samples collected from the Minnesota Health Districts during the period January through March 1966 contained less than 10 picocuries iodine-131 per liter.

Previous coverage in *Radiological Health Data and Reports:*

Period	Issue
July–December 1964	July 1965
January–June 1965	January 1966
July–December and annual summary 1965	May 1966

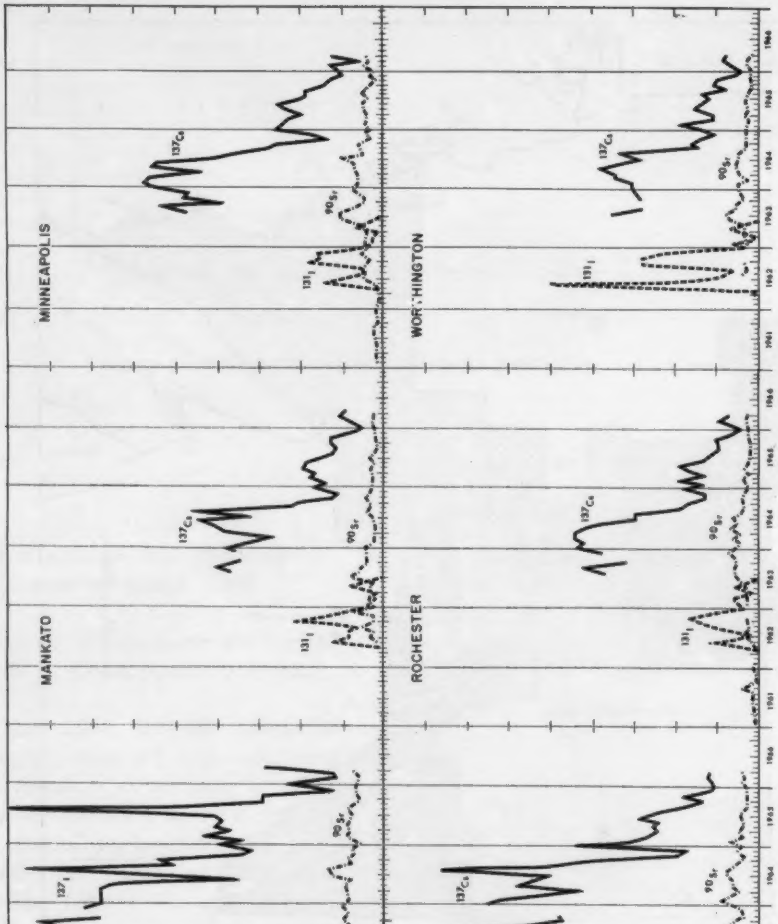

Figure 6. Radionuclide concentrations in Minnesota milk, 1962–March 1966

4. Pennsylvania Milk Network January–March 1966

Bureau of Environmental Health
Pennsylvania Department of Health

Samples of pasteurized milk are routinely collected from 10 major milk consumption areas throughout Pennsylvania (figure 7). Two samples per week are collected in Philadelphia and Pittsburgh, while weekly composite samples are collected from the other eight stations. At each sampling location, subsamples are collected from the major dairies supplying the area and are composited in proportion to the amount of milk processed by each dairy. This composite is then sent to the Radiation Laboratory of the Division of Occupational Health in Harrisburg where the weekly samples are combined for monthly analyses. Strontium–90 analyses have been carried out since April 1963.

The chemical separation technique for strontium–90 is essentially an ion exchange method described by Porter and Kahn (*2*).

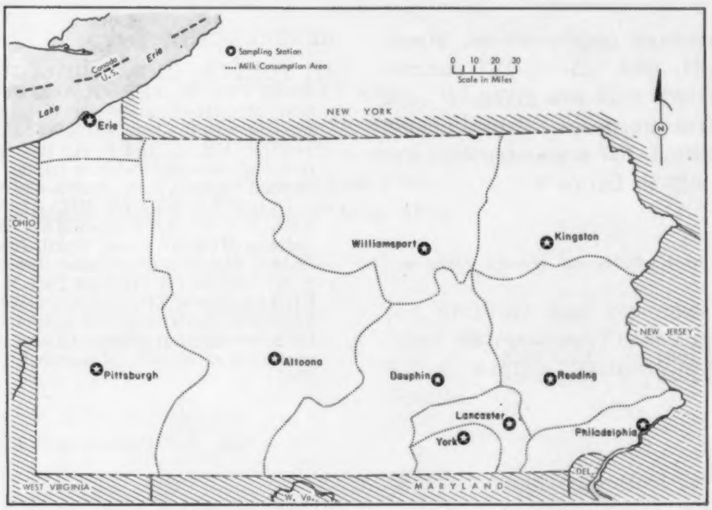

Figure 7. Pennsylvania pasteurized milk network sampling locations

Table 5. Potassium-40, strontium-90, iodine-131, and cesium-137 concentrations in Pennsylvania milk, January–March 1966

Sampling location	Potassium-40, pCi/liter			Strontium-90, pCi/liter			Iodine-131, pCi/liter			Cesium-137, pCi/liter		
	Jan	Feb	Mar	Jan	Feb	Mar	Jan	Feb	Mar	Jan	Feb	Mar
Altoona	1,063	874	915	15	20	19	<10	<10	<10	64	22	37
Dauphin	1,043	851	930	13	16	18	<10	<10	<10	60	31	30
Erie	1,066	863	980	23	20	22	<10	<10	<10	71	45	43
Kingston	1,047	832	952	19	21	17	<10	<10	<10	61	32	33
Lancaster	1,008	813	980	12	15	15	<10	<10	<10	61	27	31
Philadelphia	1,050	877	860	20	16	15	<10	<10	<10	61	24	24
Pittsburgh	1,055	806	785	19	23	20	<10	<10	<10	69	33	29
Reading	1,088	1,010	916	13	14	12	<10	<10	<10	69	35	24
Williamsport	970	876	842	22	18	18	<10	<10	<10	59	23	24
York	1,067	909	940	18	13	14	<10	<10	40	68	24	32
Average	1,046	871	910	17	18	17	<10	<10	<10	64	30	31

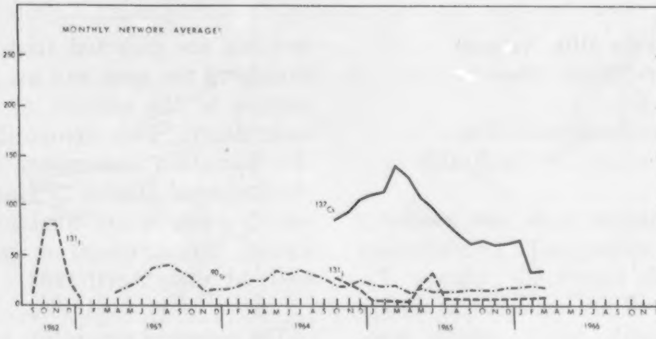

Figure 8. Radionuclide concentrations in Pennsylvania pasteurized milk, 1962-March 1966

The monthly average potassium-40, strontium-90, iodine-131, and cesium-137 concentrations in pasteurized milk are given in table 5. For comparative purposes, strontium-90, iodine-131, and cesium-137 concentrations are presented graphically in figure 8.

Previous coverage in *Radiological Health Data and Reports:*

Period	Issue
August-September 1964	February 1965
Annual summary 1964	June 1965
Annual summary 1965	May 1966

REFERENCES

(*1*) PORTER, C., D. CAHILL, R. SCHNEIDER, P. ROBBINS, W. PERRY, and B. KAHN. Determination of strontium-90 in milk by an ion-exchange method. Anal Chem 33:1306-1308 (September 1961).

(*2*) PORTER, C., and B. KAHN. Improved determinations of strontium-90 in milk by an ion-exchange method. Anal Chem 36:676-678 (March 1964).

(*3*) INDIANA STATE BOARD OF HEALTH, BUREAU OF ENVIRONMENTAL SANITATION. Indiana Milk Network, April-June 1965. Rad Health Data 6:612-614 (November 1965).

(*4*) MINNESOTA DEPARTMENT OF HEALTH and RURAL COOPERATIVE POWER ASSOCIATION. Survey of environmental radioactivity, January-June 1965, semiannual report, COO-615-17. Minnesota Department of Health, Minneapolis, Minnesota (August 1965).

FOOD AND DIET SURVEILLANCE ACTIVITIES

Efforts are being made by various Federal and State agencies to estimate the dietary intake of selected radionuclides on a continuous basis. These estimates, along with the guidance developed by the Federal Radiation Council, provide a basis for evaluating the significance of radioactivity in foods and diet.

Networks presently in routine operation and reported periodically include: (1) the Public Health Service's Institutional Total Diet Sampling Network, (2) the Atomic Energy Commission's Tri-City Diet Study, (3) the Food and Drug Administration's Teenage Diet Study, (4) the State of California's Diet Study, and (5) the State of Connecticut's Standard Diet Study. These networks provide data useful for developing estimates of nationwide dietary intakes of radionuclides. The most recent coverage of programs not reported in this issue of *Radiological Health Data and Reports* is listed below:

Program	Period reported	Last presented
Institutional Total Diet	October–December 1965	July 1966
Tri-City Diet, *HASL*	Annual summary 1965	June 1966
California Diet	May–August 1965	June 1966
Connecticut Standard Diet	January–June 1965	February 1966

1. Radionuclides in Diets for Teenagers February–November 1965

Division of Pharmacology
Food and Drug Administration

It has been estimated that males in the 16- to 19-year-old age group ingest more food daily than individuals in any other segment of the U.S. population (*1*). Therefore, the Food and Drug Administration (FDA) chose this segment for a test of the maximum radionuclide intake of all population groups. As recommended by the U.S. Department of Agriculture, (USDA) the food plan used for this test consisted of a nutritionally adequate diet at a moderate cost level for boys 16 to 19 years of age (*2*). For the purposes of the sampling program, amounts of foods selected from the 11 food groups of the USDA plan were proportioned according to the 1965 Household Food Consumption Survey (*3*).

The FDA study of radionuclides in diets for teenagers was begun on a pilot basis in May 1961 in the Washington, D.C., area. Since then, the program has expanded to include eight other cities—San Francisco, Minneapolis, St. Louis, Atlanta, Denver, Boston, Dallas, and Seattle.

Sampling and analytical procedures

To duplicate the diet of a 19-year-old male, a list of 82 different items of food and drink was prepared. Quarterly samples of these items, covering a 2-week consumption period, were purchased from national food chain stores. Efforts were made to locate the sources of the food items and to arrange representation in the samples on the broadest possible geographical basis.

The foods were prepared by professional dietitians in diet kitchens at each city in a manner comparable to domestic preparation procedures. The most acceptable home practices for washing, trimming, bone removal, and separation of wastes and cooking water were used. Representative portions of the foods (including about 8 liters of drinking water) were homogenized into a slurry, and aliquots

were analyzed for strontium-90 and cesium-137 at the nearest FDA District laboratory. Strontium-90 was separated radiochemically and its concentration determined by beta-counting, while gamma spectrometry was employed for cesium-137 analysis (*4,5*).

Results

Concentrations and daily intakes of strontium-90 and cesium-137, based on the quarterly samples for February to November 1965 are presented in tables 1 and 2. Individual station values for the quarter ending in the month shown are given along with the network averages for samples from nine cities. Denver, Colorado, generally had the highest daily strontium-90 intakes for the 1965 period, while San Francisco, California, had the lowest daily strontium-90 intake values. Minneapolis, Minnesota, had the highest daily cesium-137 intake for the 1965 period, while Dallas, Texas, had the lowest daily cesium-137 intake values.

Strontium-90

The network average daily strontium-90 intakes through November 1965 are presented in figure 1 and the range of values for the stations represented is indicated. Prior to May 1962, only one location, Washington, D.C., was sampled. The average strontium-90 intake in the diet is seen to have increased steadily from 14 pCi/day in May 1961 to 53 pCi/day in February 1964, after which it has been relatively constant, varying between 41 and 56 pCi/day, representing about one-quarter of the top of Range II (200 pCi/day) as recommended by the Federal Radiation Council (*6*).

Cesium-137

The cesium-137 average daily intakes and ranges through November 1965 are presented graphically in figure 2. The general trend of cesium-137 intakes for 1965 is downward. The peak average value, 366 pCi/day, was observed in May 1963.

Table 1. Strontium-90 concentrations and intakes in the total diet, quarterly samples, February–November 1965

Sampling locations		February		May		August		November	
		pCi/kg	pCi/day [a]	pCi/kg	pCi/day	pCi/kg	pCi/day	pCi/kg	pCi/day
Calif:	San Francisco	6	22	6	22	5	19	4	15
Colo:	Denver	9	34	17	64	19	71	24	90
D.C:	Washington	11	41	13	50	11	41	8	30
Ga:	Atlanta	NA	NA	17	64	12	45	12	45
Mass:	Boston	NA	NA	NA	NA	11	41	12	45
Minn:	Minneapolis	14	53	16	60	14	53	17	64
Mo:	St. Louis	NA	NA	12	45	12	45	NA	NA
Tex:	Dallas	8	30	11	41	8	30	8	30
Wash:	Seattle	11	41	17	64	8	30	9	34
Average		10	38	15	56	11	41	12	45

[a] Intakes based on the consumption of 3.76 kg food and drink for the 16- to 19-year-old male.
NA, no analysis performed

Table 2. Cesium-137 concentrations and intakes in the total diet, quarterly samples, February–November 1965

Sampling locations		February		May		August		November	
		pCi/kg	pCi/day [a]	pCi/kg	pCi/day	pCi/kg	pCi/day	pCi/kg	pCi/day
Calif:	San Francisco	39	147	NA	NA	33	124	22	83
Colo:	Denver	33	124	40	150	39	147	26	98
D.C:	Washington	49	184	55	207	35	132	24	90
Ga:	Atlanta	52	196	47	177	38	143	36	135
Mass:	Boston	50	188	64	241	51	192	41	154
Minn:	Minneapolis	63	237	66	248	56	211	42	158
Mo:	St. Louis	35	132	28	105	NA	NA	NA	NA
Tex:	Dallas	30	113	26	98	19	71	21	79
Wash:	Seattle	48	180	NA	NA	54	203	37	139
Average		44	165	47	177	41	154	31	117

[a] Intakes based on the consumption of 3.76 kg food and drink for the 16- to 19-year-old male.
NA, no analysis performed

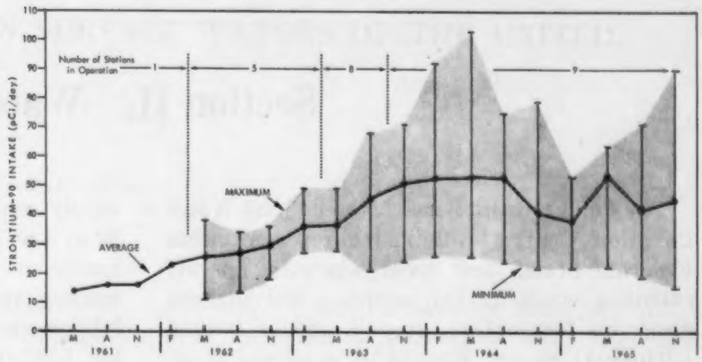

Figure 1. Averages and ranges of daily strontium-90 intake in FDA teenage standard diet

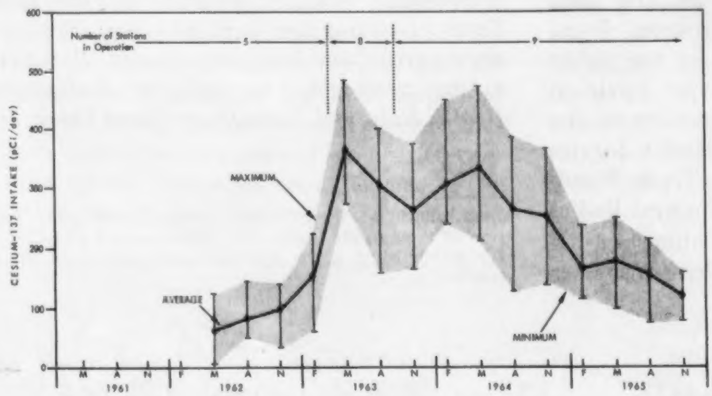

Figure 2. Averages and ranges of daily cesium-137 intake in FDA teenage standard diet

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(*1*) THE NATIONAL ACADEMY OF SCIENCES—NATIONAL RESEARCH COUNCIL. Recommended dietary allowances, National Research Council Pub 589, Revised. 2101 Constitution Avenue, Washington, D.C. 20418 (1958).

(*2*) U.S. DEPARTMENT OF AGRICULTURE. Family food plans and food costs. Home Economics Research Report No. 20. Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402 (November 1962).

(*3*) U.S. DEPARTMENT OF AGRICULTURE. Food consumption of households in the United States, household food consumption survey, Report No. 1 (1955). Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402 (December 1956).

(*4*) LAUG, E. P., A. MIKALIS, H. M. BOLLINGER, and J. M. DIMITROFF. Total diet study: A. Strontium-90 and cesium-137 content. JAOAC 46:4 (1963).

(*5*) LAUG, E. P., and J. M. DIMITROFF. Radioactivity in total diet samples. JAOAC 47:5 (October 1964).

(*6*) FEDERAL RADIATION COUNCIL. Background material for the development of radiation protection standards, Report No. 2. Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402 (September 1961).

Previous coverage in *Radiological Health Data:*

Period	Issue
May 1961–August 1962	January 1963
May 1962–February 1963	June 1963
May 1963–November 1963	April 1964
February–November 1964	July 1965

Section II. Water

The Public Health Service, the Federal Water Pollution Control Administration, and other Federal, State, and local agencies operate extensive water quality sampling and analysis programs for surface, ground, and/or treated (drinking) water. Most of these programs include determinations of gross alpha and gross beta radioactivity and/or specific radionuclides.

Although the determination of the total radionuclide intake from all sources is of primary importance, a measure of the public health importance of radioactivity levels in water can be obtained by comparison of the observed values with the Public Health Service Drinking Water Standards (*1*). These Standards, based on consideration of Federal Radiation Council (FRC) recommendations (*2–4*), set the limits for approval of a drinking water supply containing radium-226 and strontium-90 as 3 pCi/liter and 10 pCi/liter, respectively. Limits may be higher if total intake of radioactivity from all sources indicates that such intakes are within the guidelines recommended by FRC for control action. In the known absence [1] of strontium-90 and alpha emitters, the limit is 1,000 pCi/liter gross beta activity. Surveillance data from a number of Federal and State programs are published periodically to show current and long-range trends. Water programs previously reported in *Radiological Health Data and Reports* are listed below.

[1] Absence is taken to mean a negligibly small fraction of the specific limits of 3 pCi/liter and 10 pCi/liter for unidentified alpha emitters and strontium-90, respectively.

Program	Period reported	Last presented
Radiostrontium in Tap Water, *HASL*	May and July–November 1965	June 1966
Colorado River Basin Sampling Network	1962–1964	November 1965
Coast Guard Water Sampling Program	1964	November 1965
Drinking Water Analysis Program	1962	October 1965
California Water Sampling Program	January–June 1965	March 1966
Florida Water Sampling Program	1964	November 1965
Kentucky Water Sampling Program	May 1963–June 1964	March 1965
Minnesota Surface Water Sampling Program	July–December 1965	July 1966
New York Surface Water Sampling Program	June–December 1965	June 1966
North Carolina Water Sampling Program	1964	November 1965
Lower Columbia River Radiological Survey in Oregon	August 1963–July 1964	October 1965
Washington Surface Water Sampling Program	July 1964–June 1965	May 1966

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(*1*) U.S. PUBLIC HEALTH SERVICE. Drinking water standards, Revised 1962. PHS Pub No. 956. Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402 (March 1963).

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(*3*) FEDERAL RADIATION COUNCIL. Background material for the development of radiation protection standards, Report No. 1. Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402 (May 1960).

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GROSS RADIOACTIVITY IN SURFACE WATERS OF THE UNITED STATES, FEBRUARY 1966

Basic Data Program
Federal Water Pollution Control Administration
Department of the Interior

The monitoring of levels of radioactivity in surface waters of the United States was begun in 1957 as a part of the Public Health Service Water Pollution Surveillance System. Responsibility for this activity was transferred to the Federal Water Pollution Control Administration on December 31, 1965. Table 1 presents the current preliminary results of the alpha and beta analysis. The figures for gross alpha and beta radioactivity represent either determination on composites or means of weekly determinations where composites were not made. The monthly means are reported to the nearest pCi/liter. When all samples have zero pCi/liter, the mean is reported as zero; when the calculated mean is between zero and 0.5, the mean is reported as < 1 pCi/liter. The radioactivity associated with dissolved solids provides a rough indication of the levels which would occur in treated water, since nearly all suspended matter is removed by treatment processes. Strontium–90 results are reported quarterly. The stations on each river are arranged in the table according to their distance from the headwaters. Figure 1 indicates the average total beta activity in suspended-plus-

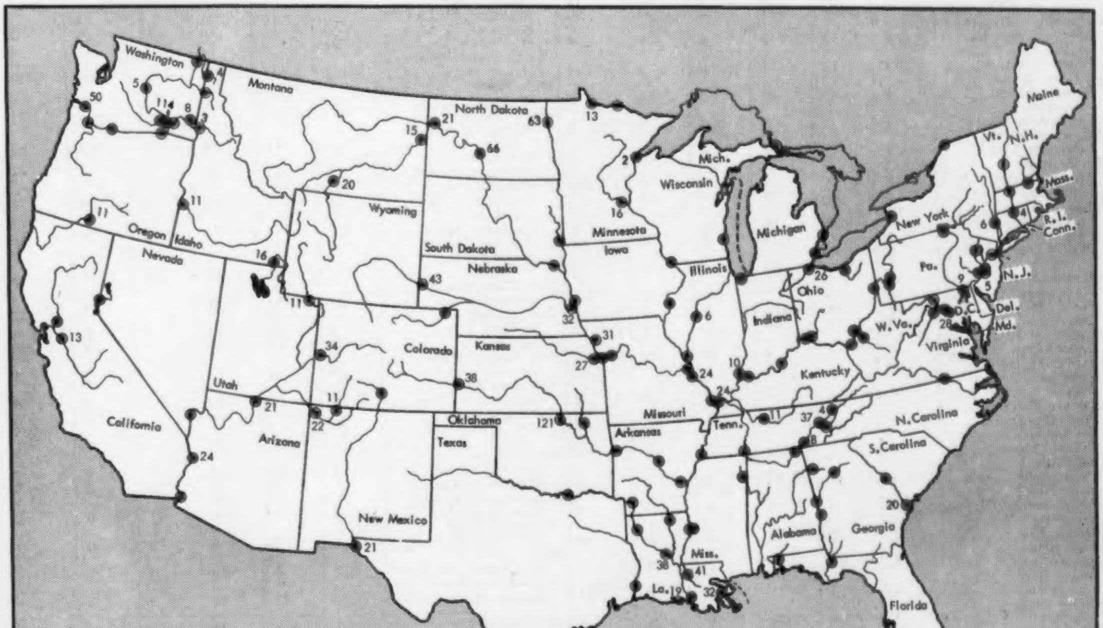

Figure 1. Sampling locations and associated total beta activity, pCi/liter, in surface waters, February 1966

dissolved solids in raw water collected at each station. A description of the sampling and analytical procedures was published in the June 1966 issue of *Radiological Health Data and Reports.*

Complete data and exact sampling locations are published in annual compilations (*1–6*) or are available on request.

Special note is taken when the alpha radioactivity is 15 pCi/liter or greater, or when the beta radioactivity is 150 pCi/liter or greater. These arbitrary levels provide a basis for the selection of certain data and for comment on the data, if needed. They reflect no public health significance as the Public Health Service drinking water standards have already provided the basis for this assessment. Changes from or toward these arbitrary levels are also noted in terms of changes in radioactivity per unit weight of solids. No discussion of gross radioactivity per gram of dissolved or suspended solids for all stations of the Water Pollution Surveillance System will be attempted at this time. Comments are made only on monthly average values. Occasional high values from single weekly samples may be absorbed into a relatively low average. When these values are significantly high, comment will be made.

Table 1. Radioactivity in raw surface waters, February 1966

Station	Average beta activity (pCi/liter)			Average alpha activity (pCi/liter)		
	Suspended	Dissolved	Total	Suspended	Dissolved	Total
Animas River:						
Cedar Hill, N. Mex	1	10	11	<1	2	2
Arkansas River:						
Coolidge, Kans	7	31	38	1	15	16
Ponca City, Okla	17	104	121	3	23	26
Atchafalaya River:						
Morgan City, La	7	12	19	3	1	4
Bear River:						
Preston, Idaho	1	15	16	0	2	2
Big Horn River:						
Hardin, Mont	2	18	20	0	6	6
Chena River:						
Fairbanks, Alaska	1	4	5	0	0	0
Clearwater River:						
Lewiston, Idaho	<1	3	3	0	1	1
Clinch River:						
Clinton, Tenn	0	4	4	0	0	0
Kingston, Tenn [a]	2	35	37	0	<1	<1
Colorado River:						
Loma, Colo	9	25	34	1	8	9
Page, Ariz	<1	21	21	0	5	5
Parker Dam, Calif-Ariz	1	23	24	0	7	7
Columbia River:						
Wenatchee, Wash	0	5	5	0	1	1
Pasco, Wash [a]	28	86	114	0	2	2
Clatskanie, Ore	16	34	50	0	1	1
Connecticut River:						
Enfield Dam, Conn	0	4	4	0	0	0
Cumberland River:						
Cheatham Lock, Tenn	6	5	11	2	0	2
Delaware River:						
Philadelphia, Pa	0	5	5	0	0	0
Great Lakes:						
Duluth, Minn	0	2	2	0	0	0
Green River:						
Dutch John, Utah	<1	11	11	0	1	1
Hudson River:						
Poughkeepsie, N.Y	0	6	6	0	0	0
Illinois River:						
Peoria, Ill	1	5	6	1	3	4
Kansas River:						
DeSoto, Kans	6	21	27	1	3	4
Klamath River:						
Keno, Ore	1	10	11	<1	0	<1
Maumee River:						
Toledo, Ohio	1	25	26	1	5	6
Mississippi River:						
St. Paul, Minn	0	16	16	0	0	0
E. St. Louis, Ill	13	11	24	3	1	4
New Roads, La	31	10	41	6	1	7
New Orleans, La	21	11	32	6	1	7
Missouri River:						
Williston, N. Dak	5	16	21	1	4	5
Bismarck, N. Dak	50	16	66	13	3	16
St. Joseph, Mo	22	9	31	5	1	6
North Platte River:						
Henry, Nebr	2	41	43	1	25	26
Ohio River:						
Cairo, Ill	19	5	24	7	0	7
Pend Oreille River:						
Albeni Falls Dam, Idaho	<1	4	4	0	<1	<1
Platte River:						
Plattsmouth, Nebr	6	26	32	2	7	9
Potomac River:						
Washington, D.C	23	5	28	8	0	8
Rainy River:						
Baudette, Minn	<1	13	13	0	0	0
Red River, North:						
Grand Forks, N. Dak	0	63	63	0	1	1
Red River, South:						
Alexandria, La	24	14	38	9	1	10
Rio Grande:						
El Paso, Tex	4	17	21	0	6	6
Laredo, Tex	3	16	19	1	5	6
San Joaquin River:						
Vernalis, Calif	3	10	13	1	2	3
San Juan River:						
Shiprock, N. Mex	9	13	22	3	3	6
Savannah River:						
Port Wentworth, Ga [a]	5	15	20	<1	0	<1
Snake River:						
Payette, Idaho	1	10	11	0	3	3
Wawawai, Wash	0	8	8	0	3	3
Susquehanna River:						
Conowingo, Md	3	6	9	1	0	1
Tennessee River:						
Chattanooga, Tenn	1	7	8	0	0	0
Wabash River:						
New Harmony, Ind	2	8	10	0	1	1
Yellowstone River:						
Sidney, Mont	1	14	15	0	4	4
Maximum	50	104	121	13	25	26
Minimum	0	2	2	0	0	0

[a] Gross beta activity at this station may not be directly comparable to gross beta activity at other stations because of the possible contribution of radionuclides from an upstream nuclear facility in addition to the contribution from fallout and naturally occurring radionuclides, common to all stations.

During January and February, the following stations showed alpha values slightly in excess of 15 pCi/liter in the dissolved solids:

North Platte River: Henry, Nebraska

Arkansas River: Coolidge, Kansas

Ponca City, on the Arkansas River, showed an increase of alpha radioactivity on dissolved solids to slightly more than 15 pCi/liter since January.

Kingston, Tennessee, on the Clinch River, and Pasco, Washington, on the Columbia River, showed a decrease in February to beta values of less than 150 pCi/liter.

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Section III. Air and Deposition

RADIOACTIVITY IN AIRBORNE PARTICULATES AND PRECIPITATION

Continuous surveillance of radioactivity in air and precipitation provides one of the earliest indications of changes in environmental fission product activity arising through air intrusions such as weapons testing fallout. To date, this surveillance has been confined chiefly to gross beta analysis. Although such data are insufficient to assess total human radiation exposure from fallout, they can be used to determine when to modify monitoring in other phases of the environment.

Surveillance data from a number of programs are published monthly and summarized periodically to show current and long-range trends of atmospheric radioactivity in the Western Hemisphere. These include data from activities of the U.S. Public Health Service, the Canadian Department of National Health and Welfare, the Mexican Commision of Nuclear Energy, and the Pan American Health Organization.

An intercomparison of the above networks was performed by Lockhart and Patterson (*1*) in 1962. In addition to those presented in this issue, the following programs were previously covered in *Radiological Health Data and Reports:*

Network	Period reported	Last reported
National Air Sampling Network	January–March 1966	July 1966
HASL Fallout Network	January–June 1965	May 1966

1. Radiation Surveillance Network April 1966

Division of Radiological Health
Public Health Service

Surveillance of atmospheric radioactivity in the United States is conducted by the Radiation Surveillance Network (RSN), which regularly gathers samples from 74 stations distributed throughout the country (figure 1). Most of the stations are operated by State health department personnel.

Daily samples of airborne particulates and precipitation are forwarded to the Radiation Surveillance Network Laboratory in Rockville, Maryland, for laboratory analysis. The alerting function of the network is provided by routine field estimates of the gross beta activity made by the station operators prior to submission of the samples. When high air levels are reported, appropriate officials are promptly notified.

Compilation of field estimates and laboratory confirmations are reported elsewhere on a monthly basis (*2*). A detailed description of the sampling and analytical procedures was presented in the December 1965 issue of *Radiological Health Data*.

Table 1 presents the monthly average gross beta activity in surface air and deposition by precipitation during April 1966. Time profiles of gross beta activity in air dating back to 1958 eight RSN stations are shown in figure 2.

Network samples for the month of April included several in which fresh fission products were identified as tabulated below.

The fresh fission products were identified with gamma scans; however, no results on individual radionuclides were derived. A possible explanation for the observed activities would be the Nevada Test Site (NTS) test of April 25, 1966, following which measurable amounts of radioactivity were observed northeast of the NTS (*3*).

Date April 1966	Location	Gross beta activity (pCi/m^3)
26	Salt Lake City, Utah	1.44
27	Denver, Colorado	0.93
	Salt Lake City, Utah	0.79
	Cheyenne, Wyoming	19.02
	Las Vegas, Nevada	0.53
28	Santa Fe, New Mexico	0.28
29	Las Vegas, Nevada	0.76

Figure 1. Radiation Surveillance Network sampling stations

Table 1. Gross beta activity in surface air and precipitation, April 1966

Station location		Number of samples		Air surveillance: Gross beta activity, pCi/m³			Precipitation		
		Air	Pptn	Maximum	Minimum	Average [a]	Last profile in *RHD&R*	Total depth (mm)	Total deposition (nCi/m²)
Ala:	Montgomery	30	2	0.27	<0.10	<0.14	Feb 66	32	<6
Alaska:	Adak	30		0.17	<0.10	<0.11	Jun 66	(c)	
	Anchorage	16	2	0.26	<0.10	<0.15	Mar 66	3	<1
	Attu Island	(b)					Jul 66	(c)	
	Fairbanks	(b)					Apr 66	(c)	
	Juneau	21	10	0.17	<0.10	<0.11	May 66	139	<28
	Kodiak	(b)					May 66	(c)	
	Nome	(b)					Dec 65	(c)	
	Pt. Barrow	27		0.12	<0.10	<0.10	Aug 66	(c)	
	St. Paul Island	30		<0.10	<0.10	<0.10	Jan 66	(c)	
Ariz:	Phoenix	28		0.50	0.12	0.20	May 66	(c)	
Ark:	Little Rock	23	7	0.17	<0.10	<0.11	Mar 66	182	<37
Calif:	Berkeley	21	2	0.29	<0.10	<0.16	May 66	18	<4
	Los Angeles	21		0.27	<0.10	<0.13	Dec 65	(c)	
C.Z:	Ancon	16		<0.10	<0.10	<0.10	May 66	(c)	
Colo:	Denver	29	5	0.93	<0.10	<0.16	May 66	23	<5
Conn:	Hartford	28	9	0.17	<0.10	<0.11	Apr 66	27	<5
Del:	Dover	19		0.13	<0.10	<0.10	Feb 66	(c)	
D.C:	Washington	29	7	0.14	<0.10	<0.10	Aug 66	79	<16
Fla:	Jacksonville	29	7	0.22	<0.10	<0.12	Mar 66	37	<8
	Miami	26	4	0.21	<0.10	<0.12	Apr 66	15	<3
Ga:	Atlanta	1	5	0.11	0.11	0.11	Jan 66	88	<18
Guam:	Agana	29		<0.10	<0.10	<0.10	Feb 66	(c)	
Hawaii:	Honolulu	29	1	0.18	<0.10	<0.11	Jul 66	8	<2
Idaho:	Boise	28	3	0.19	<0.10	<0.12	Jul 66	27	<5
Ill:	Springfield	29	6	0.14	<0.10	<0.10	Aug 66	163	<33
Ind:	Indianapolis	28	10	0.16	<0.10	<0.11	Jan 66	80	<16
Iowa:	Iowa City	30	7	0.12	<0.10	<0.10	May 66	81	<16
Kans:	Topeka	29	5	0.31	<0.10	<0.12	Mar 66	48	<10
Ky:	Frankfort	25	9	0.17	<0.10	<0.11	Aug 66	61	<12
La:	New Orleans	28	9	0.22	<0.10	<0.11	Aug 66	126	<25
Maine:	Augusta	30	9	0.19	<0.10	<0.11	Dec 65	31	<6
	Presque Isle	22		0.14	<0.10	<0.10	May 66	(c)	
Md:	Baltimore	20	5	0.14	<0.10	<0.10	Apr 66	50	<10
	Rockville	16		0.12	<0.10	<0.10	Jul 66	(c)	
Mass:	Lawrence	30	8	0.16	<0.10	<0.11	Feb 66	29	<6
	Winchester	28	7	0.17	<0.10	<0.10	Jun 66	25	<5
Mich:	Lansing	29	12	0.13	<0.10	<0.10	Jul 66	75	<15
Minn:	Minneapolis	20	6	0.12	<0.10	<0.10	Feb 66	24	<5
Miss:	Jackson	24	6	0.15	<0.10	<0.11	Dec 65	157	<32
Mo:	Jefferson City	30	11	0.20	<0.10	<0.11	Jan 66	142	<28
Mont:	Helena	30	7	0.26	<0.10	<0.13	Jun 66	20	<4
Nebr:	Lincoln	18	2	0.24	<0.10	<0.12	Jan 66	10	<2
Nev:	Las Vegas	26		0.76	<0.10	0.26	Apr 66	(c)	
N.H:	Concord	18		0.22	<0.10	<0.12	Aug 66	(c)	
N.J:	Trenton	30	4	0.19	<0.10	<0.11	Dec 65	8	<2
N. Mex:	Sante Fe	29	1	0.28	<0.10	<0.15	Jun 66	1	<1
N.Y:	Albany	19	4	0.16	<0.10	<0.11	Jan 66	24	<5
	Buffalo	29		0.13	<0.10	<0.10	May 66	(c)	
	New York	28		0.15	<0.10	<0.10	Jun 66	(c)	
N.C:	Gastonia	30	9	0.20	<0.10	<0.12	May 66	35	<7
N. Dak:	Bismarck	28	2	0.16	<0.10	<0.11	Aug 66	29	<6
Ohio:	Cincinnati	18		<0.10	<0.10	<0.10	Feb 66	(c)	
	Columbus	30	10	0.24	<0.10	<0.12	Dec 65	78	<16
	Painesville	30	8	0.18	<0.10	<0.11	Apr 66	69	<14
Okla:	Oklahoma City	29	9	0.13	<0.10	<0.10	Jul 66	80	<16
	Ponca City	27	5	<0.10	<0.10	<0.10	Apr 66	65	<13
Ore:	Portland	29	6	0.33	<0.10	<0.19	Jan 66	23	<5
Pa:	Harrisburg	29	3	0.13	<0.10	<0.10	Jan 66	49	<10
P.R:	San Juan	29	3	0.16	<0.10	<0.11	Dec 65	111	<22
R.I:	Providence	28	5	0.16	<0.10	<0.10	Jul 66	31	<6
S.C:	Columbia	28	4	0.18	<0.10	<0.11	Jun 66	35	<7
S. Dak:	Pierre	29	2	0.17	<0.10	<0.11	May 66	11	<2
Tenn:	Nashville	29	11	0.14	<0.10	<0.10	Jul 66	105	<21
Tex:	Austin	29	5	0.14	<0.10	<0.11	Feb 66	91	<18
	El Paso	30	2	0.26	<0.10	<0.14	Aug 66	29	<6
Utah:	Salt Lake City	29	5	1.44	<0.10	<0.22	Dec 65	42	<9
Vt:	Barre	26	7	0.18	<0.10	<0.12	Mar 66	17	<3
Va:	Richmond	30	6	0.14	<0.10	<0.10	Mar 66	56	<11
Wash:	Seattle	30	8	0.12	<0.10	<0.10	Mar 66	43	<9
	Spokane	29	1	0.17	<0.10	<0.13	Feb 66	1	<1
W. Va:	Charleston	30	12	0.16	<0.10	<0.10	Jun 66	109	<22
Wis:	Madison	30	6	0.12	<0.10	<0.10	Mar 66	34	<7
Wyo:	Cheyenne	29	4	19.02	<0.10	<0.75	Apr 66	16	<3
Network summary		1,840	325	19.02	<0.10	<0.12		54	<11

[a] The monthly average is calculated by weighting the individual samples with length of sampling period. Values of <0.10 are assumed to be 0.10 for averaging purposes. If the < values represent more than 10 percent of the average, a less-than sign is placed before the average.
[b] Indicates no report received.
[c] Indicates no precipitation sample collected.

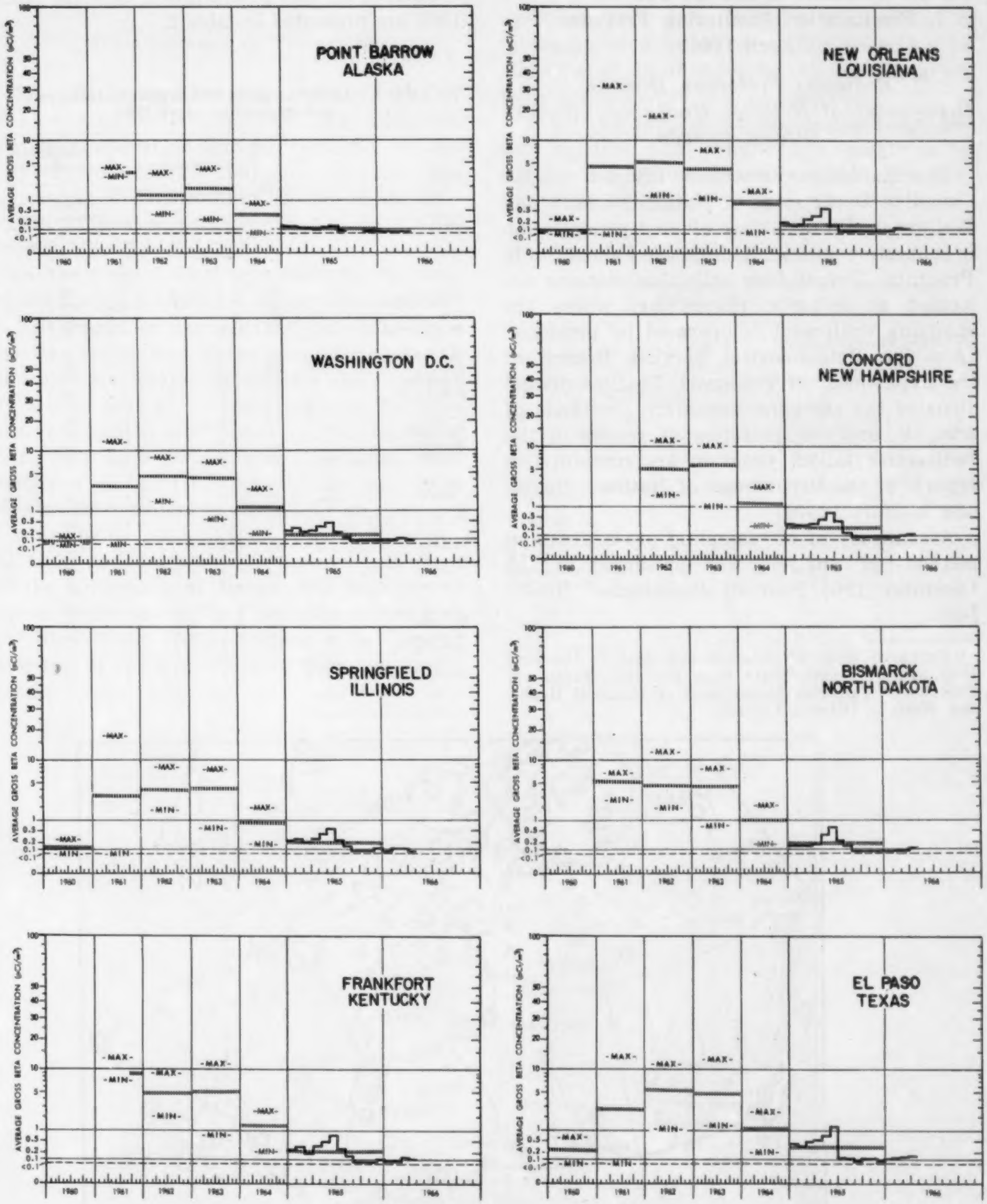

Figure 2. Monthly and yearly profiles of beta activity in air—Radiation Surveillance Network, 1960–April 1966

2. Canadian Air and Precipitation Monitoring Program April 1966[1]

Radiation Protection Division
Department of National Health and Welfare
Ottawa, Canada

The Radiation Protection Division of the Canadian Department of National Health and Welfare monitors surface air and precipitation in connection with its Radioactive Fallout Study Program. Twenty-four collection stations are located at airports (figure 3), where the sampling equipment is operated by personnel from the Meteorological Services Branch of the Department of Transport. Detailed discussions of the sampling procedures, methods of analysis, and interpretation of results of the radioactive fallout program are contained in reports of the Department of National Health and Welfare (*3–7*).

A summary of the sampling procedures and methods of analysis was presented in the December 1965 issue of *Radiological Health Data.*

[1] Prepared from information and data in the May 1966 monthly report "Data from Radiation Protection Programs," Canadian Department of National Health and Welfare, Ottawa, Canada.

Surface air and precipitation data for April 1966 are presented in table 2.

Table 2. Canadian gross beta activity in surface air and precipitation, April 1966

Station	Number of samples	Air surveillance (activity, pCi/m³)			Precipitation measurements	
		Maximum	Minimum	Average	Average concentration (pCi/liter)	Total deposition (nCi/m²)
Calgary	30	0.2	0.0	0.1	42	1.8
Coral Harbour	30	0.2	0.0	0.1	46	0.5
Edmonton	29	0.2	0.0	0.1	80	1.4
Ft. Churchill	28	0.2	0.0	0.1	70	1.9
Ft. William	29	0.2	0.0	0.1	53	1.7
Fredericton	28	0.2	0.0	0.1	95	1.5
Goose Bay	30	0.2	0.0	0.1	72	1.4
Halifax	30	0.2	0.0	0.1	80	1.9
Inuvik	30	0.2	0.0	0.1	126	0.8
Montreal	29	0.2	0.0	0.1	95	2.0
Moosonee	30	0.2	0.0	0.1	29	1.2
Ottawa	30	0.2	0.0	0.1	47	1.1
Quebec	30	0.2	0.0	0.1	121	2.2
Regina	30	0.3	0.0	0.1	28	1.1
Resolute	30	0.1	0.0	0.1	NS	NS
St. John's, Nfld	30	0.2	0.0	0.1	48	2.5
Saskatoon	30	0.2	0.0	0.1	75	1.3
Sault Ste. Marie	29	0.2	0.0	0.1	47	2.0
Toronto	30	0.2	0.0	0.1	75	2.5
Vancouver	30	0.2	0.0	0.1	79	2.0
Whitehorse	30	0.3	0.0	0.1	56	0.7
Windsor	28	0.2	0.0	0.1	28	2.5
Winnipeg	30	0.2	0.0	0.1	38	1.8
Yellowknife	30	0.2	0.0	0.1	37	0.8
Network summary		0.2	0.0	0.1	64	1.6

NS, no sample reported.

Figure 3. Canadian air and precipitation sampling stations

3. Mexican Air Monitoring Program December 1965

National Commission of Nuclear Energy

The Radiation Surveillance Network of Mexico was established by the Comisión Nacional de Energía Nuclear (CNEN), Mexico City. From 1952 to 1961, the network was directed by the Institute of Physics of the University of Mexico, under contract to the CNEN (*8–12*).

In 1961, the CNEN appointed its Division of Radiological Security (DRS) to establish a new radiation surveillance network. This network consists of 17 stations (figure 4), 12 of which are located at airports and operated by airline personnel. The remaining five stations are located at Mexico City, Mérida, Veracruz, San Luis Potosí, and Ensenada. Staff members of the DRS operate the station at Mexico City, while the other four stations are manned by members of the Centro de Previsión del Golfo de México, the Chemistry Department of the University of Mérida, the Instituto de Zonas Deserticas of the University of San Luis Potosí, and the Escuela Superior de Ciencias Marinas of the University of Baja California, respectively.

Details of sampling procedures were presented in the December 1965 issue of *Radiological Health Data*. Samples are counted a minimum of 3 or 4 days after collection to allow for decay of radon and thoron. Data are not extrapolated to time of collection.

The maximum, minimum, and average fission product beta activity concentrations in surface air during December 1965 are presented in table 3.

Table 3. Mexican gross beta activity of airborne particulates, December 1965

Station	Number of samples	Gross beta activity, pCi/m³		
		Maximum	Minimum	Average
Acapulco	9	<0.1	<0.1	<0.1
Ciudad Juarez	15	0.4	<0.1	<0.1
Chihuahua	21	0.7	<0.1	0.1
Ensenada	11	0.2	<0.1	<0.1
Guadalajara	16	0.5	<0.1	0.2
Guaymas	13	0.2	<0.1	<0.1
La Paz	22	0.1	<0.1	<0.1
Matamoros	NS			
Mazatlán	20	0.1	<0.1	<0.1
Mérida	13	0.1	<0.1	<0.1
Mexico, D.F	17	0.2	<0.1	<0.1
Nuevo Laredo	8	0.1	<0.1	<0.1
San Luis Potosí	16	0.1	<0.1	<0.1
Tampico	16	0.1	<0.1	<0.1
Torreón	31	0.3	<0.1	<0.1
Tuxtla Gutierrez	NS			
Veracruz	16	0.1	<0.1	<0.1

NS, no sample collected—station temporarily shut down.

Figure 4. Fallout network sampling stations in Mexico

4. Pan American Air Sampling Program April 1966

Pan American Health Organization and U.S. Public Health Service

Gross beta activity in air is monitored by countries in the Americas under the auspices of the collaborative program developed by the Pan American Health Organization (PAHO) and the U.S. Public Health Service (PHS) to assistant PAHO-member countries in developing radiological health programs. The sampling equipment and analytical services are provided by the Division of Radiological Health, PHS, and are identical with those employed for the Radiation Surveillance Network. The air sampling station locations are shown in figure 5.

The April 1966 air monitoring results from the participating countries are given in table 4.

Table 4. PAHO gross beta activity in surface air, April 1966

Station location	Number of samples	Gross beta activity, pCi/m³		
		Maximum	Minimum	Average [a]
Argentina: Buenos Aires	4	<0.10	<0.10	<0.10
Chile: Santiago	25	<0.10	<0.10	<0.10
Jamaica: Kingston	21	0.12	<0.10	<0.10
Peru: Lima	18	<0.10	<0.10	<0.10
Venezuela: Caracas	12	<0.10	<0.10	<0.10
West Indies: Trinidad	17	<0.10	<0.10	<0.10
Pan American summary	97	0.12	<0.10	<0.10

[a] The monthly average is calculated by weighting the individual samples with length of sampling period. Values of <0.10 are assumed to be 0.10 for averaging purposes. If more than 10 percent of the samples contain <0.10 pCi/m³, a less-than sign is placed before the average.

Figure 5. Pan American Air Network sampling stations

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Section IV. Other Data

This section presents results from routine sampling of biological materials and other media not reported in the previous sections. Included are such data as those obtained from human bone sampling, bovine thyroid sampling, and environmental monitoring reports.

ENVIRONMENTAL LEVELS OF RADIOACTIVITY AT ATOMIC ENERGY COMMISSION INSTALLATIONS

The U.S. Atomic Energy Commission receives from its contractors semiannual reports on the environmental levels of radioactivity in the vicinity of major Commission installations.[1] The reports include data from routine monitoring programs where operations are of such a nature that plant environmental surveys are required.

Releases of radioactive materials from AEC installations are governed by radiation standards set forth by AEC's Division of Operational Safety in directives published in the "AEC Manual."[2]

Summaries of the environmental radioactivity data follow for the Pinellas Peninsula Plant and the Savannah River Plant.

[1]Copies of these reports are available from the Division of Public Information, Atomic Energy Commission, Washington, D.C. 20545.

[2] Part 20, "Standards for Protection Against Radiation," AEC Rules and Regulations, contains essentially the standards published in the "AEC Manual." The AEC Rules and Regulations are available from the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402, on a subscription basis at $3.50 for 3 years.

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1. Pinellas Peninsula Plant July–December 1965 [3]

General Electric Company
St. Petersburg, Florida

Pinellas Peninsula Plant, shown in figure 1, is an electronic component production facility. The Plant maintains an environmental monitoring program to measure the levels of radioactive environmental contamination associated with plant effluents. These measurements serve as an index of the effectiveness of the plant's contamination control measures. Environmental monitoring includes sampling of a single combined sewer effluent, milk from three local dairy farms, and air and surface water obtained at locations suggested by meterological conditions and radioactivity discharge concentrations. Except for air samples, which may also contain tritium gas, the radioactive portion of the samples is essentially tritium oxide.

Air monitoring

Air samples are obtained periodically in areas up to 2 miles downwind from the exhaust stack. Analysis of the one sample collected during the sampling period revealed no detectable amounts of tritium gas or tritium oxide. The limit of detection is 9,600,000 pCi/m^3 for tritium gas and 5,000 pCi/m^3 for tritium oxide.

Sewer effluent monitoring

A combined sewer effluent sample is obtained daily near the perimeter of the Plant's property. During the sampling period, six of 110 samples analyzed showed detectable concentrations of tritium (> 90,000 pCi/liter)[4]. The maximum concentration, 500,000 pCi/liter, was caused by radioactivity in the cooling water discharged from the Plant's incinerator during the burning of low level contaminated wastes. Calculations based on radioactivity releases from the process waste system, the incinerator, and the Plant's water discharges indicate that the average tritium concentration in the com-

[3] Summarized from "Environmental Monitoring, July 1 through December 31, 1965," General Electric Company, Pinellas Peninsula Plant, St. Petersburg, Florida.

[4] Expressions in parentheses indicate limits of detectability in the respective environmental samples.

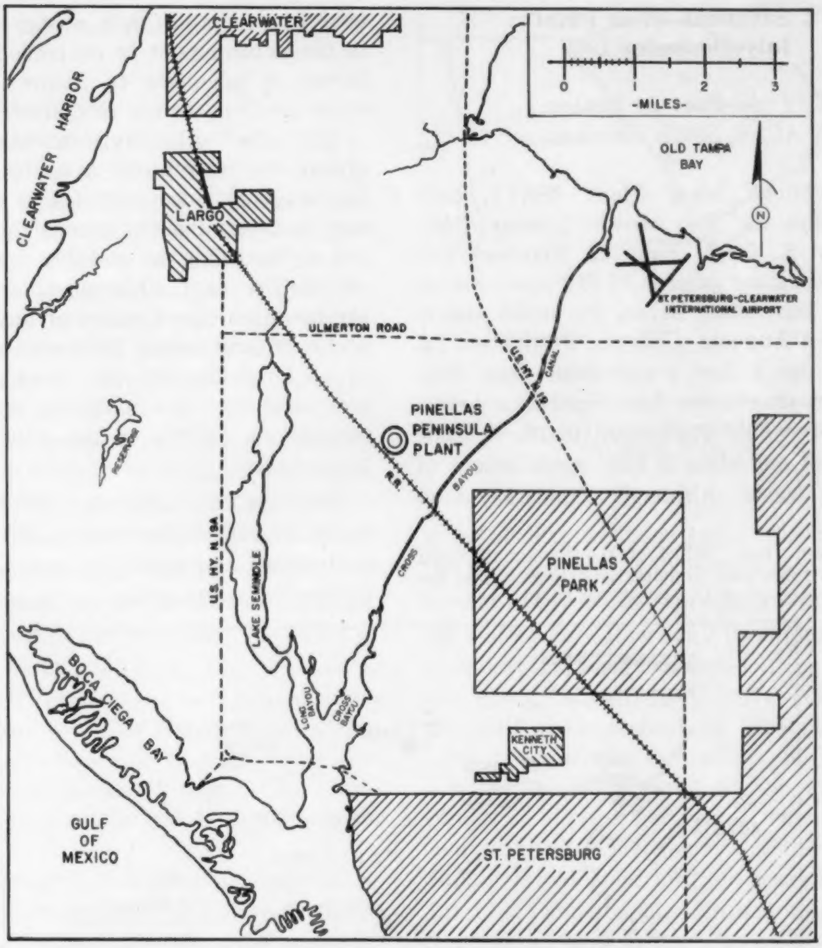

Figure 1. Location of the Pinellas Peninsula Plant

bined sewer effluent for the second half of 1965 was less than 0.8 percent of the AEC standard.

Surface water sampling

Surface water samples are collected at monthly intervals at selected locations within 8 miles of the plant. The sampling areas are determined by interrelating the concentrations of radioactivity in exhaust stack effluent with meteorological data. There were no indications of tritium oxide (> 90,000 pCi/liter) in the 46 surface water samples analyzed during the sampling period.

Milk sampling results

Fifteen samples of raw milk were collected from farms within a 3-mile radius of the plant. These samples were analyzed by the Florida State Board of Health during 1965. No detectable concentrations (> 90,000 pCi/liter) of tritium were evident.

Previous coverage in *Radiological Health Data and Reports:*

Period	Issue
1960–1961	July 1962
Calendar year 1962	June 1963
Calendar year 1963	September 1964
January–June 1964	February 1965
July–December 1964	August 1965
January–June 1965	February 1966

2. Savannah River Plant July–December 1965[5]

E. I. du Pont de Nemours
Aiken, South Carolina

The Savannah River Plant (SRP), built and operated for the Atomic Energy Commission by E. I. du Pont de Nemours and Company, occupies an area of 312 square miles along the Savannah River, 22 miles downstream from Augusta, Georgia. Production facilities include a fuel preparation area, four operating reactors, two fuel separation areas, and a heavy-water production plant. A basic goal in plant operation is total containment of radioactive waste. Although some very low-level gaseous and liquid wastes are discharged to the environment in controlled releases, dispersal is adequate to insure environmental concentrations below recommended guides.

The DuPont environmental monitoring group has maintained a continuous monitoring program since 1951 (prior to plant startup) to determine the concentrations of radioactive materials in a 1,200-square-mile area outside the plant. This surveillance determines the magnitude and origin of any radioactivity above natural levels. Measured concentrations of radionuclides in air, water, and milk are compared with the maximum permissible concentrations (MPC) in the AEC Manual (see footnote 2).

Sensitive instruments, which can detect traces of radioactive materials far below concentrations of hazard significance, are used to determine radioactivity in the environs. Maxi-

[5] Summarized from "Effect of the Savannah River Plant on Environmental Radioactivity, Semiannual Report, July–December 1965" (DPST-66-30-1).

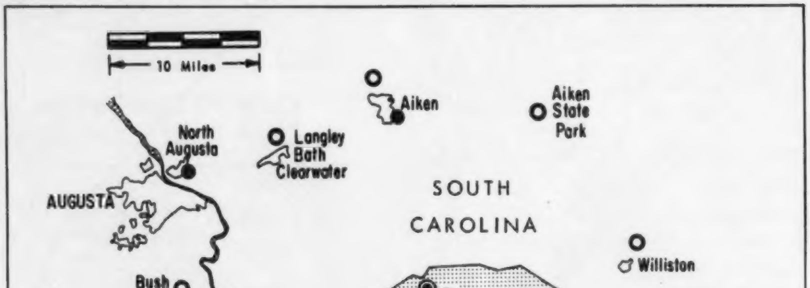

Figure 2. Environmental sampling locations, Savannah River Plant

mum and minimum values are given for individual samples collected during the reporting period.

Atmospheric monitoring

Concentrations of radioactive materials in the atmosphere were measured by weekly analyses of air filters collected at five monitoring stations near the plant perimeter and nine stations around a circle of about a 25-mile radius from the center of the plant (figure 2). Deposition rates of radioactive materials in rainwater at each station were also determined by monthly analyses of ion exchange columns (fallout collectors). The monitoring stations are spaced so that a significant plant release of airborne activity would be detected regardless of the prevailing wind. All stations operate continuously. Four additional air monitoring stations at Savannah and Macon, Georgia, and at Columbia and Greenville, South Carolina, are so distant from the plant that the effect of SRP operations is negligible; they are reference points for determining background activity levels (figure 3). This system permits comprehensive surveillance of atmospheric radioactivity and also makes it possible to differentiate between weapons test fallout and plant releases.

The small amount of radioactive material released to the atmosphere, primarily from the fuel separations areas, was obscured by fallout

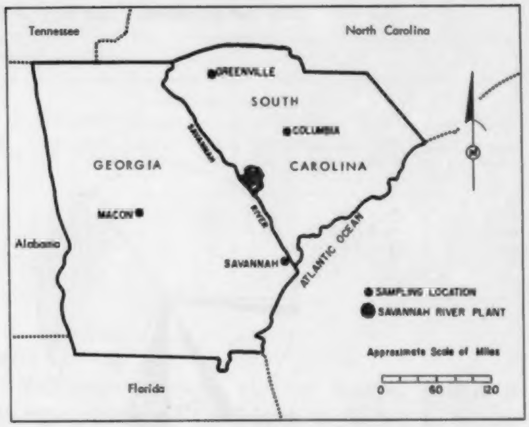

Figure 3. Distant air monitoring stations Savannah River Plant

from nuclear weapons tests. The influence of the weapons tests, which were resumed in September 1961, is shown in figure 4. Concentrations after July 1965 are only slightly above the lowest average ever observed at the plant (0.02 pCi/m^3 in August 1961). The relative abundance of airborne radionuclides since January 1963 is shown in figure 5. The diminishing activity is proportional to the areas of the circles (and circle segments) which show average activity for each year. Fresh weapons tests fallout is indicated by the presence of ruthenium–103 and barium-lanthanum–140 during 1963 and 1964. Fallout from the Chinese nu-

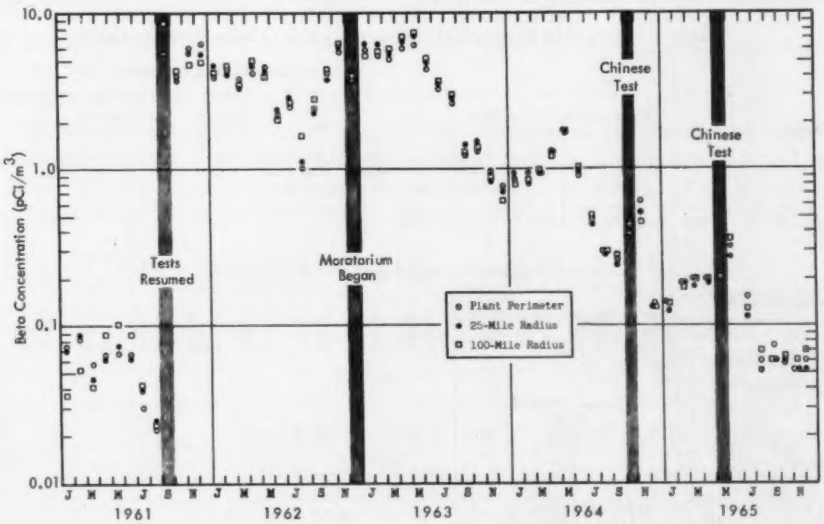

Figure 4. Influence of weapons tests

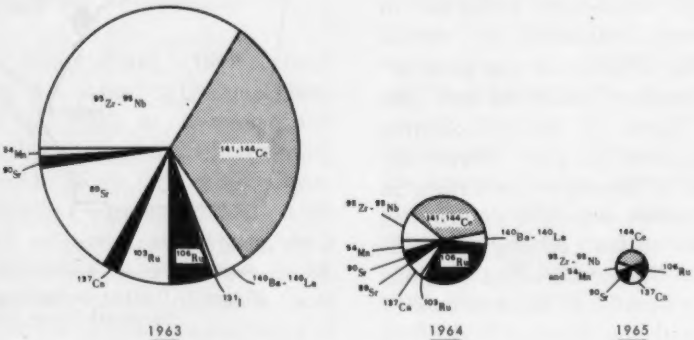

Figure 5. Relative abundance of airborne radionuclides (weapons test fallout)

clear detonation in May 1965 was low compared to the levels after the Chinese test in October 1964; the presence of short radioactive half-life barium-lanthanum-140 in high-volume air samples confirmed the presence of fresh fission products.

Radioactivity in air, determined from filter analyses, is shown in table 1. The July–December 1965 concentrations of filterable beta activity (0.07 pCi/m^3) and alpha activity (0.0007 pCi/m^3) in air were 0.07 percent and 1.8 percent of their respective MPC's. Tritium oxide concentrations in air, measured continuously at the plant perimeter and at the 25-mile stations, did not exceed 1.1 percent of the MPC. Iodine–131, ruthenium–106, zirconium-niobium–95, and manganese–54 concentrations in air samples were less than their respective detection limits throughout the entire period.

Deposition of radioactive materials during the second half of 1965 totaled 3.86 nCi/m^2 at plant perimeter locations and 3.47 nCi/m^2 at the 25-mile-radius locations; comparable values for the first half of 1965 were 21.6 nCi/m^2 and 24.7 nCi/m^2, respectively. Deposition at each sampling location is recorded in table 2.

Table 1. Savannah River Plant radioactivity in air, July–December 1965

Filter analyses	Average concentrations, pCi/m^3																
	Plant perimeter locations						25-mile-radius locations										
	A	B	C	D	E	Average	Aiken Airport	Aiken State Park	Allendale	Barnwell	Bushfield	Langley	Sardis	Waynesboro	Williston	Highway 301	Average
Alpha emitters in air [a] (multiply by 10^{-3})																	
Maximum	1.2	1.3	1.2	1.2	1.1		1.2	1.2	1.1	1.5	1.1	1.2	0.9	1.0	1.3	1.2	
Minimum	0.4	0.4	0.3	0.3	0.3		0.4	<0.3	0.4	<0.3	<0.3	0.3	0.3	0.5	0.3	<0.3	
Average	0.7	0.8	0.7	0.7	0.6	0.7	0.7	0.5	0.7	0.6	0.6	0.7	0.5	0.6	0.6	0.5	0.6
Nonvolatile beta emitters in air [b]																	
Maximum	0.29	0.26	0.28	0.26	0.27		0.14	0.14	0.12	0.14	0.12	0.13	0.13	0.12	0.15	0.12	
Minimum	0.04	0.03	0.03	0.04	0.04		0.04	0.02	0.04	0.04	0.03	0.03	0.03	0.03	0.04	0.04	
Average	0.08	0.07	0.07	0.08	0.08	0.08	0.07	0.07	0.07	0.07	0.06	0.06	0.06	0.06	0.07	0.07	0.06
Specific radionuclides in air (averages)	Composite sample						Composite sample										
Cesium-137	0.01						0.01										
Cerium-141	0.02						0.02										
Ruthenium-106	ND						ND										
Zirconium-niobium-95	ND						ND										
Manganese-54	ND						ND										

[a] Sensitivity of analysis—0.3 pCi/m^3: MPC—40 pCi/m^3
[b] Sensitivity of analysis—0.006 pCi/m^3: MPC—100 pCi/m^3
ND, nondetectable.

Table 2. Total fallout deposited, Savannah River Plant, July–December 1965

Radionuclide	Deposition, nCi/m²																
	Plant perimeter locations						25-mile-radius locations										
	A	B	C	D	E	Average	Aiken Airport	Aiken State Park	Allendale	Barnwell	Bushfield	Langley	Sardis	Waynesboro	Williston	Highway 301	Average
Alpha [a]	0.93	1.78	3.36	1.00	1.12	1.62	1.89	2.70	1.04	2.08	1.12	4.36	1.81	1.35	0.85	4.32	2.16
Strontium-90	1.12	1.00	0.85	0.97	1.12	1.00	0.77	0.93	0.66	0.89	0.77	0.97	0.89	1.04	0.89	1.12	0.89
Cesium-137	1.00	1.51	1.08	1.47	1.78	1.35	0.66	1.47	0.89	0.66	0.54	1.31	0.42	1.54	1.16	1.66	1.04
Cerium-144	1.16	1.89	1.35	1.93	2.20	1.70	1.70	1.39	2.32	1.43	1.08	1.81	0.77	1.27	1.62	3.78	1.70
Beryllium-7	8.49	15.8	17.8	15.8	17.0	15.1	7.3	10.4	7.0	3.9	4.2	12.0	2.7	7.3	7.3	17.0	7.7

[a] Multiply by 10^{-2}

Vegetation

Radioactive contamination of vegetation may result from direct deposition on exposed surfaces or absorption of radioactivity from the soil. Bermuda grass was selected for analysis because of its importance as a pasture grass for dairy herds and its availability during all seasons of the year.

Grass samples were collected at seven locations along the Plant perimeter and at nine other locations along a 25-mile radius route. (These are not designated on figure 2.) Samples from each quadrant of the Plant and of the surrounding area were composited for monthly analysis. Radionuclides in grass samples were from weapons test fallout. Alpha emitters averaged 0.1 pCi/g, dry weight, at the plant perimeter and 25-mile radius locations, as compared to 0.2 pCi/g during the first half of 1965; gamma emitters averaged 22.3 and 17.5 pCi/g, dry weight (including an average of 8 pCi/g of beryllium–7), respectively, as compared to 64 pCi/g and 40 pCi/g for the first half of 1965. Radioisoptic concentrations found in grass samples are presented in table 3. While the exact nature of the alpha activity decrease (about twofold) is not known, the change is commensurate with previously observed changes which appear to be seasonal.

Milk

Milk was sampled at four dairies within a 25-mile radius of the Plant as shown in figure 2. Samples were taken weekly and analyzed for tritium, iodine–131, and cesium–137. Strontium–90 determinations were made quarterly. Milk produced in the area and sold by major distributors was also analyzed for these radionuclides. Results from analyzing milk for radioactivity during July–December 1965 are given in table 4.

The average concentrations of three radionuclides in milk (20 pCi/liter for strontium–90, <5 pCi/liter for iodine–131, and 47 pCi/liter for cesium–137) were consistent with values reported by the U.S. Public Health Service for most sections of the United States. Tritium in local milk, when present, is assumed to be associated with Plant operations. The average tritium level was less than the sensitivity of the analysis which allows detection of concentrations of 3,000 pCi/liter (1 percent of the MPC).

Algae and fish in the Savannah river

Fish (predominantly bream) and indigenous algae, primarily green (*Vaucheria*) and blue-green (*Phormidium*), were collected weekly

Table 3. Radioactivity on vegetation, July–December 1965

	Concentration, pCi/g, dry weight					
	Alpha	Cesium-137	Cerium-144	Ruthenium-106	Manganese-54	Beryllium-7
Sensitivity of analysis	0.10	0.07	0.32	0.45	0.05	0.60
Plant perimeter (7 locations)						
Maximum	0.40	4.9	15.4	6.4	1.0	12.0
Average	0.13	2.6	7.5	2.2	0.6	9.4
25-mile radius (7 locations)						
Maximum	0.44	1.8	17.8	6.9	0.8	10.1
Average	0.12	1.3	6.0	2.2	0.5	7.5

Table 4. Radioactivity in milk from local dairies, July–December 1965

	Concentration, pCi/liter				
	Aiken	Allendale	North Augusta	Waynesboro Georgia	Major distributors [a]
Tritium [b]					
Maximum	6,000	5,000	7,000	5,000	5,000
Minimum	<3,000	<3,000	<3,000	<3,000	<3,000
Average	<3,000	<3,000	<3,000	<3,000	<3,000
Strontium-90 [c]					
September	13	18	19	18	22
December	18	16	22	23	27
Cesium-137 [d]					
Maximum	105	95	59	103	80
Minimum	<25	<25	<25	<25	<25
Average	50	43	43	51	48

[a] Milk produced in local dairies, but sold by major distributors
[b] Sensitivity of analysis—3,000 pCi/liter; MPC—300,000 pCi/liter
[c] Sensitivity of analysis—1.6 pCi/liter
[d] Sensitivity of analysis—25 pCi/liter; MPC—2,000 pCi/liter

upstream, adjacent to, and downstream from the Plant. Determination of radionuclides in algae is important because algae concentrate certain radionuclides and form a part of the food chain of aquatic organisms. Data from the analysis of fish and algae samples are given in table 5. Beta concentrations in algae and fish adjacent to and downstream from the Plant indicate some Plant contribution. Although measurably higher than similar material collected at the control station 3 miles upstream from the Plant, the slight increase is of no biological significance.

Water monitoring

The Plant site is drained by five streams which flow several miles through the reservation before reaching the river (figure 6). In January 1965, the Beaufort-Jasper Water Authority began operation of a new treatment facility to furnish sanitary water, partially supplied from the Savannah River, to most of Beaufort County, South Carolina. Water is supplied through a new canal from the river at

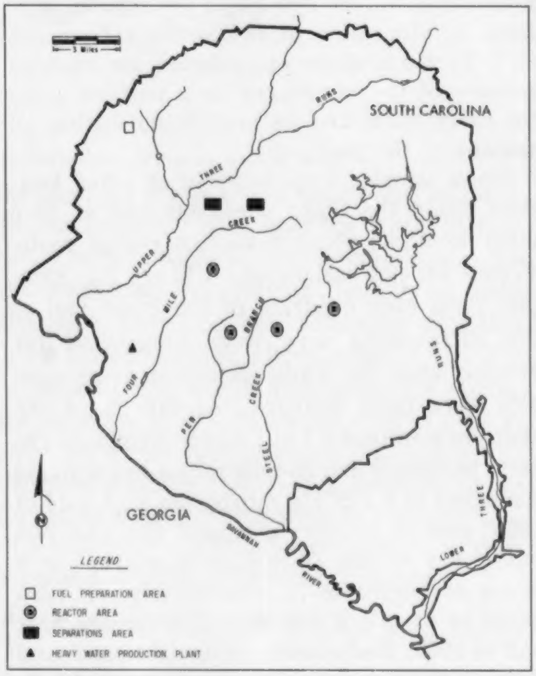

Figure 6. SRP production areas and effluent streams

Table 5. Radioactivity in Savannah River aquatic specimens, July–December 1965

Location	Nonvolatile beta emitters, pCi/g [a]										
	Algae, dry weight				Fish, wet weight						
						Bone			Flesh		
	Number of samples	Maximum	Minimum	Average	Number of samples	Maximum	Minimum	Average	Maximum	Minimum	Average
Control (3 miles upstream from Plant)	2	160	37	98	30	140	ND	27	8	1	4
Along Plant boundary	4	1,250	98	570	30	270	10	58	21	1	6
Highway 301 crossing (10 miles downstream from Plant)	20	740	38	120	30	260	8	51	48	1	9

[a] Sensitivity of analysis—varied due to differing sample size
ND, less than sensitivity of the analysis.

Table 6. Radioactivity in public water supplies

	Concentration, pCi/liter														
	Aiken	Allendale	Augusta	Barnwell	Bath	Blackville	Clearwater	Jackson	Langley	New Ellenton	North Augusta	Sardis	Waynesboro	Williston	Average
Alpha emitters [a]															
Maximum	2.3	0.2	0.5	0.7	4.0	0.7	1.1	24.0	2.3	3.6	0.2	0.4	0.3	1.2	
Minimum	1.0	<0.2	<0.2	<0.2	1.1	<0.2	<0.2	6.0	0.6	0.7	<0.2	<0.2	<0.2	0.2	
Average	1.6	<0.2	<0.2	0.2	2.4	0.3	0.3	13.3	1.4	1.9	<0.2	<0.2	<0.2	0.6	1.7
Nonvolatile beta emitters [b]															
Maximum	5	5	8	7	11	4	5	42	6	18	6	14	17	4	
Minimum	<4	<4	<4	<4	<4	<4	<4	8	<4	4	<4	<4	<4	<4	
Average	<4	<4	4	<4	8	<4	<4	25	4	8	<4	4	5	<4	6

[a] Sensitivity of analysis—0.2 pCi/liter; MPC—10 pCi/liter
[b] Sensitivity of analysis—4.0 pCi/liter; MPC—3,000 pCi/liter

a location about 90 miles below the Savannah River Plant site. The city of Savannah also supplements its domestic well water supply with river water during periods of peak demand.

Communities near the plant get domestic water from deep wells or surface streams. Public water supplies from 14 surrounding towns are collected and analyzed monthly. Concentrations of alpha activity (1.7 pCi/liter) and beta activity (6 pCi/liter) are essentially the same as those observed before plant startup in 1951. Analytical results are given in table 6.

River water, analyzed weekly, was sampled continously at four locations (upstream, adjacent to, and as far as 10 miles downstream) as shown in figure 2. Concentrations of alpha and nonvolatile beta emitters in river water for the past year are summarized in table 7; average concentrations of specific radionuclides found in the river water during July–December 1965 are in table 8.

Table 7. Radioactivity in Savannah River water July–December 1965

	Concentration, pCi/liter			
	Control (3 miles upstream from Plant)	Plant perimeter 1	Plant perimeter 2	Highway 301 (10 miles downstream from Plant)
Alpha emitters [a]				
July–December 1965:				
Maximum	0.7	0.7	0.4	0.3
Minimum	<0.2	<0.2	<0.2	<0.2
Average	0.2	<0.2	<0.2	<0.2
January–June 1965:				
Average	0.3	0.2	0.2	<0.2
Nonvolatile beta emitters [b]				
July–December 1965:				
Maximum	20	58	37	31
Minimum	<4	<4	4	<4
Average	6	18	13	10
January–June 1965:				
Average	8	13	13	10

[a] Sensitivity of analysis—0.2 pCi/liter; MPC—10 pCi/liter
[b] Sensitivity of analysis—4.0 pCi/liter; MPC—3,000 pCi/liter

Table 8. Average concentration of radionuclides in Savannah River water, July–December 1965

Radionuclide	Concentration, pCi/liter			
	Sensitivity of analysis	Control (3 miles upstream from plant)	Highway 301 (10 miles downstream from plant)	Percent MPC at Highway 301
Tritium	600	1,000	12,400	4.1
Ruthenium-103, -106	3.2	<3.2	<3.2	<0.10
Cerium-141, -144	2.5	<2.5	<2.5	<0.08
Cesium-134, -137	0.6	<0.6	2.2	0.11
Neptunium-239	0.9	<0.9	<0.9	<0.003
Barium-lanthanum-140	1.6	<1.6	<1.6	<0.02
Zirconium-niobium-95	0.5	<0.5	<0.5	<0.02
Chromium-51	4.3	<4.3	8.6	0.001
Strontium-89	0.3	<0.3	<0.3	—
Iodine-131	0.5	<0.5	0.7	—
Strontium-90	0.01	1.2	2.1	—
Cobalt-60	1.4	<1.4	<1.4	<0.01
Zinc-65	1.1	<1.1	<1.1	<0.01
Manganese-54	0.4	<0.4	<0.4	<0.001

Cesium–137, strontium–90, chromium–51, iodine–131, tritium, and trace amounts of zirconium-niobium–95, released mainly from reactor areas, were the radionuclides of plant origin detectable in river water at the downstream location. The average concentration of zirconium-niobium–95 was less than the sensitivity of the analysis. Strontium–90 and tritium from worldwide fallout were also detected in river water upstream from the Plant. Average concentrations of all radionuclides found in river water during July–December 1965 were only small fractions of the permissible concentrations. The tritium concentrations in finished water collected from the Beaufort-Jasper Water Plant averaged 5,400 pCi/liter (1.8 percent of the MPC) during the 6-month period.

Tritium (^3H), a beta emitter and the most abundant radionuclide released to the river, is produced by neutron irradiation of heavy-water moderator in the reactors. Chromium-51, the second most abundant radionuclide released to the river, is produced by neutron irradiation of stable chromium (a component of the stainless steel used in reactor parts). The concentrations of tritium and chromium-51 in river water averaged 4.1 percent and 0.001 percent of their respective MPC. Average concentrations of all radionuclides found in river water during July–December 1965, as shown in table 8, were only small fractions of the permissible concentrations.

Environmental gamma radiation levels

Monthly measurements of environmental gamma radiation were made with portable Geiger-Mueller survey instruments. July–December 1965 data in table 9 are characteristic of individual station observations during the past several years; the readings are not precise, but are sufficiently accurate to illustrate any significant variations above background. The differences among the values shown are within the variability anticipated due to differences in normal background and in instrument response characteristics.

Summary

The quantity of radioactive waste released by the Savannah River Plant to its environs was, for the most part, too small to be distinguished from natural background radiation, or was obscured by worldwide fallout from nuclear weapons testing during past years. Beta activity in air, which shows no relationship to plant operations, was about one-fifth that for the same period of 1964. Radioactive materials in fish flesh continued to be far below levels considered significant from a health standpoint. The average concentration of radionuclides in river water did not exceed 4.1 percent of the maximum permissible concentrations.

Table 9. Environmental gamma radiation, Savannah River Plant, July–December 1965

	Exposure, mR/day																
	Plant perimeter locations						25-mile-radius locations										
	A	B	C	D	E	Average	Aiken Airport	Aiken State Park	Allendale	Barnwell	Bush field	Langley	Sardis	Waynesboro	Williston	Highway 301	Average
Maximum	0.62	0.54	0.49	0.43	0.41		0.40	0.39	0.51	0.49	0.41	0.44	0.40	0.39	0.41	0.40	
Minimum	0.25	0.25	0.32	0.24	0.23		0.20	0.21	0.21	0.24	0.26	0.22	0.22	0.19	0.27	0.23	
Average	0.39	0.34	0.37	0.32	0.33	0.35	0.32	0.29	0.32	0.35	0.33	0.33	0.32	0.30	0.35	0.32	0.32

Previous coverage in *Radiological Health Data and Reports:*

Issue	Period
July–December 1961	September 1962
Calendar Year 1962	August 1963
Calendar Year 1963	August 1964
January–June 1964	February 1965
July–December 1964	August 1965
January–June 1965	February 1966

Section V. Technical Notes

PLUTONIUM IN AIRBORNE PARTICULATES NOVEMBER 1965–MARCH 1966

J. Russell, H. Levine, and *R. Schneider*[1]

The Radiation Surveillance Network (RSN) of the Division of Radiological Health, Public Health Service, located at Rockville, Maryland, initiated routine analysis for plutonium in air particulates during 1965 as part of its mission to establish, maintain, and operate a national surveillance network to measure radioactivity in the environment (*1*). Plutonium has been injected into the atmosphere by the detonation of nuclear devices (*2*), and its determination in air is of interest because inhalation is believed to be the principal route of nonoccupational exposure (*3*).

Air filters from 11 RSN stations are analyzed monthly for plutonium. Each daily filter is counted for gross beta activity and for gamma emitters by gamma spectroscopy 4 or 5 days after collection. For plutonium analysis, a monthly composite is made of one-half of each individual sample for each station. Each composite, representing 20,000 to 30,000 cubic meters of air, is analyzed by gamma spectroscopy prior to the plutonium analysis.

The air particulate samples are collected on carbon-loaded cellulose filters. The filter is mounted on the vacuum side of a positive displacement lobar impeller pump in a special filter holder with orifice, designed by the RSN staff. Air flow is determined by a gauge which reads the pressure drop across the orifice and is calibrated in cubic feet per minute.

The air filters are ashed in a platinum crucible, brought completely into solution with a nitric acid-hydrofluoric acid treatment, converted to the chloride ion and brought to volume in a volumetric flask. The solution is then divided into two aliquots, 70 percent and 30 percent, and each aliquot analyzed and counted separately for total plutonium according to the procedure of Levine and Lamanna (*4*). The total activity is the sum of the results for both aliquots. The chemical yield of the analytical procedure is approximately 80 percent as determined by spiked samples. The samples are counted for 1,000 minutes in a 2-inch-diameter, 0.080 mg/cm^2-window proportional counter.

The counting error at the 95-percent confidence level is less than 10 percent for most of the samples, and the accuracy of the air flow measurement is estimated to be within 5 percent. The precision of the analytical procedure is estimated to be approximately 20 percent at the 1 pCi activity level, based upon the results of the two aliquots.

The results for November 1965 through March 1966, in picocuries per 1,000 cubic meters, are presented in table 1. It should be noted that the stations selected for plutonium analysis were changed from El Paso to Austin, Texas, and from Spokane to Seattle, Washington, beginning in February 1966.

[1] Mr. Russell is chief, Radiation Surveillance Network; Mr. Levine is chemist, Radiation Surveillance Network; and Mr. Schneider is experimental physicist, Office of Assistant Chief for Technical Development, all in the Technical Oprations Branch, Division of Radiological Health, PHS.

Table 1. Plutonium in airborne particulates November 1965–March 1966 [a]

Station location	Plutonium content, pCi/m^3				
	Nov 1965	Dec 1965	Jan 1966	Feb 1966	Mar 1966
Alaska: Anchorage	0.048	0.061	0.077	0.105	0.074
Arizona: Phoenix	0.114	0.089	0.144	0.181	0.041
Colorado: Denver	0.090	0.079	0.090	0.107	0.085
Hawaii: Honolulu	0.045	0.052	0.104	0.085	0.070
Louisiana: New Orleans	0.066	0.096	0.084	0.113	0.138
Maryland: Rockville	0.054	0.069	0.078	0.079	0.066
New York: Buffalo	0.051	0.038	0.068	0.051	0.078
North Carolina: Gastonia	0.095	0.145	0.086	0.096	0.120
South Dakota: Pierre	0.094	0.081	0.089	0.080	0.089
Texas: Austin	—	—	—	0.137	0.153
El Paso	0.039	0.069	0.034	—	—
Washington: Seattle	—	—	—	0.043	0.080
Spokane	0.057	0.056	0.048	—	—

[a] Plutonium includes plutonium-238, plutonium-239, and plutonium-240.

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REPORTED NUCLEAR DETONATIONS, JULY 1966

During July 1966, one U.S. nuclear test at the Nevada Test Site was announced by the Atomic Energy Commission, and two French nuclear tests in the Pacific were announced by French authorities.

The U.S. test was in the low-yield range (equivalent force of less than 20 kilotons of TNT), conducted underground on July 28, 1966. This test was part of the Commission's "Plowshare Program" to develop peaceful uses for nuclear explosives. In this instance, the test was one of a series to develop devices for use in possible later excavation experiments.

French test Headquarters at Tahiti announced that a plutonium fission device, described as one of "tactical" size, was exploded July 2, 1966, over a lagoon off the uninhabited Pacific atoll Moruroa, about 750 miles southeast of Tahiti. Another French nuclear test conducted in the same area on July 19, 1966, involved a nuclear device dropped from an airplane. The French announcements of the test indicated that this device would be one of low yield.

SYNOPSES

Synopses of reports, incorporating a list of key words, are furnished below in reference card format for the convenience of readers who may wish to clip them for their files.

STRONTIUM-90 CONCENTRATIONS OBSERVED IN U.S. PASTEURIZED MILK COMPARED WITH PRECIPITATION AND STRONTIUM-90 IN DEPOSITION AND IN SOIL, 1960-1963. *H. L. Fisher, J. R. Coleman,* and *R. D. Grundy. Radiological Health Data and Reports,* Vol. 7, August 1966, pp. 427-439.

Annual averages of strontium-90 concentrations in milk were compared with precipitation, strontium-90 deposition, and strontium-90 in soil for the years 1960 to 1963 on the basis of a linear relationship. This relationship may be useful for limited predictions of future strontium-90 concentrations in milk. As expected, higher concentrations of strontium-90 were found in milk from areas of higher concentrations of strontium-90 in soil, and higher milk concentrations seemed to be associated with increased rainfall. Although it was clear that increased deposition of strontium-90 was related to its concentration in milk, variations in the relationship remain to be studied on the basis of the specific transport mechanisms involved.

KEY WORDS: deposition, milk, precipitation, soil, strontium-90.

RADON-222 IN NATURAL GAS. *Louis A. Bunce* and *Frank W. Sattler. Radiological Health Data and Reports,* Vol. 7, August 1966, pp. 441-444.

In the preoperational phase of a study to determine the effect of an underground nuclear detonation on radon levels in natural gas, baseline levels of radon-222 have been measured during 1965 in natural gas from 307 producing wells in the proposed test area. Average radon-222 levels in natural gas from formations sampled varied from 2.7 to 66.9 pCi/liter, with a maximum observed value of 158.8 pCi/liter. Assuming combustion in a room without discrete ventilation, radon-222 buildup from an original fuel concentration of 50 pCi/liter could produce a room concentration of 1 pCi/liter. This estimated concentration equals the maximum exposure level permitted by regulations of the State of New Mexico (based on NCRP limits) under conditions on continuous or general population exposure. Normal use of natural gas would not be expected to produce radon-222 concentrations in excess of these recommended limits.

KEY WORDS: Colorado, natural gas, New Mexico, Project Gasbuggy, radon-222.

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SYMBOLS, UNITS, AND EQUIVALENTS

Symbols	Units	Equivalents
BeV	billion electron volts	equals GeV
Ci	curie	3.7×10^{10} dps
cm	centimeter(s)	0.394 inch
cpm	counts per minute	
dpm	disintegrations per minute	
dps	disintegrations per second	
eV	electron volts	1.6×10^{-12} ergs
g	gram(s)	
GeV	giga electron volts	1.6×10^{-3} ergs
kg	kilogram(s)	1,000 g = 2.205 lb
km^2	square kilometer(s)	
kVp	kilovolt peak	
m^3	cubic meter(s)	
mA	milliampere(s)	
mCi/mi^2	millicuries per square mile	0.386 nCi per square meter (mCi/km^2)
MeV	million (mega) electron volts	1.6×10^{-6} ergs
mg	milligram(s)	
mi^2	square mile(s)	
ml	milliliter(s)	
mm	millimeter(s)	
nCi/m^2	nanocuries per square meter	2.59 mCi per square mile
pCi	picocurie(s)	10^{-12} curie = 2.22 dpm
R	roentgen	
rad	unit of absorbed radiation dose	100 ergs per gram

INTERNATIONAL NUMERICAL MULTIPLE AND SUBMULTIPLE PREFIXES

Multiples and submultiples	Prefixes	Symbols	Pronunciations
10^{12}	tera	T	tĕr' a
10^{9}	giga	G	jĭ' ga
10^{6}	mega	M	mĕg' a
10^{3}	kilo	k	kĭl' o
10^{2}	hecto	h	hĕk' to
10	deka	da	dĕk' a
10^{-1}	deci	d	dĕs' i
10^{-2}	centi	c	sĕn' ti
10^{-3}	milli	m	mĭl' i
10^{-6}	micro	μ	mī' kro
10^{-9}	nano	n	năn' o
10^{-12}	pico	p	pē' co
10^{-15}	femto	f	fĕm' to

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